EXHIBIT 19

Libby Site-wide Human Health Risk Assessment (HHRA) Addendum for Asbestos (June 12, 2018)

- FINAL -

Addendum: Site-wide Human Health Risk Assessment
Libby Asbestos Superfund Site
Libby, Montana

June 2018

Prepared by:

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Addendum: Site-wide Human Health Risk Assessment
Libby Asbestos Superfund Site,
Libby, Montana

FINAL - June 2018

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Table of Contents

List of Tables

List of Figures

Appendices

Acronyms and Abbreviations

%	percent
>	greater than
≥	greater than or equal to
µm	micrometers
ABS	activity-based sampling
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
BNSF	Burlington Northern and Santa Fe
CDM Smith	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	conceptual site model
CTE	central tendency exposure
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ET	exposure time
FS	feasibility study
Grace	W.R. Grace Company
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
ISO	International Organization of Standardization
IUR	inhalation unit risk
LA	Libby amphibole asbestos
LPT	localized pleural thickening
Ms/g	million structures per gram
NPL	National Priorities List
NIOSH	National Institute of Occupational Safety and Health
NPL	National Priorities List
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PCM	phase contrast microscopy
PCME	phase contrast microscopy-equivalent
RAGS	Risk Assessment Guidance for Superfund
RfC	reference concentration
RI	remedial investigation
RME	reasonable maximum exposure
ROD	record of decision
s/cc	structures per cubic centimeter of air
SAP	sampling and analysis plan
Site	Libby Asbestos Superfund Site

Acronyms and Abbreviations (cont.)

TEM	transmission electron microscopy
TWF	time-weighting factor
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VI	vermiculite insulation

Section 1

Introduction

This document is an addendum to the *Site-wide Human Health Risk Assessment (Site-wide HHRA)* for the Libby Asbestos Superfund Site (Site) in Libby, Montana, released by the U.S. Environmental Protection Agency (EPA) in November 2015 (EPA 2015). This risk assessment addendum presents newly collected exposure data (collected in 2016) used to estimate the health risks to people who may breathe asbestos in air at the Site.

Because this document is an addendum to the *Site-wide HHRA*, the risk characterization methodology and approach are briefly summarized in this document. A detailed discussion is provided in the *Site-wide HHRA* (EPA 2015).

1.1 Site Background

Libby is a community located near a former vermiculite mine in northwestern Montana (**Figure 1-1**). The vermiculite mine near Libby began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company (Grace) from approximately 1963 to 1990. Operations at the mine included mining and milling of the vermiculite ore.

Vermiculite from the mine near Libby contains varying concentrations of asbestos. The vermiculite deposit near Libby contains a distinct form of naturally occurring amphibole asbestos comprised of a range of mineral types and morphologies. The U.S. Geological Survey (USGS) performed electron probe micro-analysis and x-ray diffraction analysis of 30 samples collected from asbestos veins at the mine (Meeker et al. 2003). The results indicated there were several mineral varieties of amphibole asbestos present, including (in order of decreasing abundance) winchite, richerite, and tremolite, with lower levels of magnesio-riebeckite, edenite, and magnesio-arfvedsonite. The mixture of asbestos present at the Site is referred to as Libby amphibole asbestos or LA[1].

While the mine was in operation, the milling process released airborne particulates into the atmosphere. In addition, waste products and off-specification materials were made available to the public. Further, vermiculite products were used in numerous private residences, businesses, and public buildings across the Site.

Historical mining, milling, and processing operations and bulk transfer of mining-related materials, tailings, and waste to locations throughout the Kootenai Valley are known to have resulted in releases of LA to the environment. Epidemiological studies revealed workers at the mine had an increased risk of developing asbestos-related lung disease (McDonald et al. 1986a, 1986b, 2004; Amandus and Wheeler 1987; Amandus et al. 1987a, 1987b; Whitehouse 2004; Sullivan 2007). Although the mine ceased operations in 1990, historical or continuing releases of LA from mine-related materials could be serving as a source of ongoing exposure and risk to individuals at the Site.

In October 2002, the Site was listed on the National Priorities List (NPL), making it eligible to receive additional federal funds for investigation and removals. In 2009, for the first time in the history of the

[1] The *Toxicological Review of Libby Amphibole Asbestos* (EPA 2014) uses the acronym LAA.

federal government, EPA and the Department of Human Health Services declared a Public Health Emergency in Libby to provide federal health care assistance for victims of asbestos-related disease.

For long-term management purposes, the Site has been divided into eight operable units (OUs):

- OU1, Former Export Plant
- OU2, Former Screening Plant
- OU3, Mine
- OU4, Libby Residential/Commercial Areas
- OU5, Former Stimson Lumber Mill
- OU6, BNSF Railroad
- OU7, Town of Troy
- OU8, Roadways

1.2 Site-wide HHRA Risk Conclusions

The *Site-wide HHRA* estimated potential risks to people from exposure to LA at the Site. Because people may be exposed by multiple exposure scenarios, often across multiple OUs, potential exposures and risks were evaluated on a site-wide basis, incorporating data from all eight OUs, to provide a representation of potential cumulative exposures.

More than 150 different exposure scenarios were evaluated in the *Site-wide HHRA* (EPA 2015). There were few exposure scenarios that, when considered alone, yielded reasonable maximum exposure (RME) non-cancer[2] hazard quotients (HQs) that exceeded 1. These exposure scenarios include (listed from highest to lowest HQ below):

- Tradesperson exposures during active source disturbance activities, such as vermiculite insulation (VI) removal or demolition, inside residential and commercial properties in Libby and Troy

- Outdoor worker exposures during disturbances of subsurface soils with LA contamination (when soil concentrations were at or above 0.2% LA by mass)

- Residential and outdoor worker exposures during disturbances of surface soils with detectable LA concentrations

- Outdoor worker exposures during commercial logging activities in OU3 near the mine (within about 1 mile), especially those logging activities that disturb soil and duff material (e.g., skidding, site restoration)

- Firefighter exposures while performing dry mop-up activities after an understory burn that occurs near the mine (within about 1 mile)

- Residential and indoor commercial worker exposures to indoor air during active source disturbance activities inside properties where one or more interior removal triggers are present (i.e., at “pre-removal” properties)

[2] As described in the Site-wide HHRA, for LA, non-cancer exposure is a more sensitive metric of potential concern than cancer risk.

- Forest worker exposures while building slash piles near the mine (within about 1 mile)
- Rockhound exposures in the disturbed area of the mine in OU3
- Residential exposures during woodstove ash disturbances (i.e., while emptying ash from the woodstove) when firewood is collected from near the mine (within about 1 mile)

In addition to the above exposure scenarios, although quantitative risk estimates were not calculated, the *Site-wide HHRA* concluded non-cancer HQs also have the potential to be above a level of concern if individuals disturb subsurface soils in OU1 and OU2 where LA contamination has been left at depth following soil remediation (EPA 2015).

There were also several exposure scenarios that, when considered alone, yielded RME non-cancer HQs that approached or equaled 1 (e.g., brush-hogging along roadways in OU8, residential exposures while digging in subsurface soil with LA concentrations at or above 0.2% LA by mass). Although these exposure scenarios alone do not result in unacceptable risks, they have the potential to be important contributors to cumulative risk.

Results of the *Site-wide HHRA* helped to inform Site managers and the public about the magnitude of potential risks attributable to LA and to guide the selection of final remedial actions for the Site. The Record of Decision (ROD) for OU4 through OU8[3] was finalized in February 2016 (EPA 2016).

The Feasibility Study (FS) for OU3 is still in progress. In support of the OU3 FS, additional field investigations have been conducted in OU3 to further characterize the spatial pattern of estimated risks within OU3. In particular, additional exposure data were collected in 2016 to evaluate two exposure scenarios of interest: 1) outdoor worker exposures during commercial logging activities, and 2) residential exposures during woodstove ash disturbances (i.e., while emptying ash from the woodstove) when firewood is collected locally.

1.3 Document Purpose and Organization

This document is an addendum to the *Site-wide HHRA* (EPA 2015). The purpose of this addendum is to present supplemental risk estimates that incorporate the new exposure data collected in 2016 from OU3. In addition to this introduction (**Section 1**), this document is organized as follows:

- **Section 2 –** This section presents a brief overview of the risk characterization approach, including the exposure assessment, toxicity assessment, and risk estimation methodology used to quantify cancer risks and non-cancer hazards to humans exposed to LA.
- **Section 3 –** This section presents the quantitative estimates of cancer risk and non-cancer hazard to humans exposed to LA during disturbances of woodstove ash generated from firewood.
- **Section 4 –** This section presents the quantitative estimates of cancer risk and non-cancer hazard to humans exposed to LA in outdoor air during soil/duff disturbance activities.

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[3] The RODs are complete for OU1 and OU2. The ROD for OU3 will be prepared separately from the other OUs (i.e., OU4–OU8).

- **Section 5 –** This section presents a brief overview of the uncertainty assessment and discusses the sources of uncertainty in the risk estimates for human receptors.
- **Section 6 –** This section presents the overall risk assessment conclusions.
- **Section 7 –** This section provides full citations for all EPA guidance documents, reports, analytical methods, Site-related documents, and scientific publications referenced in this addendum.

All referenced tables, figures, and appendices are provided at the end of this document.

Section 2

Risk Characterization Approach Overview

The methods used to evaluate human health risks from LA are in basic accordance with EPA guidelines for evaluating risks at Superfund sites (EPA 1989), including the *Framework for Investigating Asbestos-Contaminated Superfund Sites (Asbestos Framework)* (EPA 2008), which has been specifically developed to support evaluations of exposure and risk from asbestos.

Because this document is an addendum to the *Site-wide HHRA*, the risk characterization methodology and approach are briefly summarized in this document. A detailed discussion is provided in the *Site-wide HHRA* (EPA 2015).

2.1 Exposure Assessment

Exposure is the process by which receptors come into contact with contaminants in the environment. This subsection summarizes the exposure media, exposure scenarios, and human populations of potential concern at the Site. This section also describes how LA exposures were quantified and the derivation of the exposure point concentrations (EPCs) used in the risk characterization.

2.1.1 Conceptual Site Model

Historical mining, milling, and processing operations, use of vermiculite in building materials, transport of mining-related materials, tailings, waste, and runoff from the mine site are known to have released LA to the environment. Additionally, past geologic and geomorphic processes on Vermiculite Mountain have eroded and deposited naturally occurring LA in soils throughout the Site. People may be exposed to LA by two exposure routes: inhalation and ingestion. Of these two exposure routes, inhalation exposure of LA is considered the greatest concern (EPA 2015).

Asbestos fibers in source materials are typically not inherently hazardous, unless the asbestos is released from the source material into air where it can be inhaled (EPA 2008). Asbestos fibers may become airborne in many ways, such as natural forces (wind blowing over a contaminated soil) or human activities that disturb contaminated sources. **Figure 2-1** presents the conceptual site model (CSM) that depicts how LA in source media can be transported in the environment to exposure media that humans may encounter at the Site.

2.1.2 Exposure Scenarios and Populations

The amount of LA in air, and hence the amount inhaled, will vary depending on the level of LA in the exposure medium, which can vary from location to location, and the intensity and duration of the disturbing force. Because of this, it is convenient to stratify inhalation exposure scenarios according to the disturbance activity and the location where the disturbance activity occurs. The *Site-wide HHRA* quantified inhalation exposures and risks for a wide range of disturbance activities and exposure populations, including residents, recreational visitors, teachers/students, and several types of workers (indoor workers, local tradespeople, outdoor workers). This addendum will evaluate exposures for two specific exposure populations:

- Outdoor workers during soil/duff disturbances associated with commercial logging activities; and
- Residents during woodstove ash disturbances (i.e., while emptying ash from the woodstove) when firewood is collected locally.

2.1.3 Exposure Parameters

Exposure estimates in a human health risk assessment do not seek to evaluate exposures for specific individuals. Rather, risk estimates are calculated for representative members of the exposure population, calculating risks based on members of the population with "typical" levels of exposure and members of the population with "high-end" exposures. These two exposure estimates are referred to as central tendency exposure (CTE) and RME, respectively.

For each exposure scenario, information on estimated exposure time (ET, in hours per day), exposure frequency (EF, in days per year), and exposure duration (ED, in years) is used to derive a lifetime time-weighting factor (TWF) as follows:

$$TWF = ET/24 \cdot EF/365 \cdot ED/70$$

The value of the TWF ranges from zero to one and describes the average fraction of a lifetime during which the specific exposure scenario occurs. The selected exposure parameters for each exposure scenario evaluated in this risk assessment addendum are discussed and presented in each risk characterization section (i.e., Section 3 and Section 4).

2.1.4 Exposure Areas

An exposure area is the location where exposure and risk are to be evaluated. It is assumed that random exposure occurs over the entire exposure area; thus, the risk is related to the mean concentration across the entire exposure area (EPA 1992). Therefore, the EPC is an estimate of the average concentration of LA in air at the exposure area.

Because of the complex nature of the source materials in the forested areas and the difficulty in establishing a reliable quantitative relationship between LA levels in source materials and ABS air, when evaluating exposures in the forested area surrounding the mine in the *Site-wide HHRA* (EPA 2015), exposure areas were designated as a function of distance from the mined area (as measured from the approximate center point for the mined area) — near the mine (within 2 miles of the mined area), intermediate from the mine (about 2-6 miles from the mined area), far from the mine (greater than 6 miles from the mined area), and outside the NPL boundary. The distance cut-offs were established based on a qualitative interpretation of patterns of LA concentrations in source media (soil, duff, bark), which showed concentrations were highest within about 2 miles of the mine and decreased with increasing distance from the mine. Outdoor ABS data within each exposure area were grouped together for the purposes of calculating EPCs in the forested areas in the *Site-wide HHRA* (EPA 2015).

In 2016, an investigation was conducted in OU3 to collect additional ABS air samples for two specific ABS scenarios – during hooking/skidding activities and during woodstove ash removal activities. Specific investigation-design information is included in the *Sampling and Analysis Plan/Quality Assurance Project Plan: 2016 Woodstove Ash and Hooking/Skidding Activity Based Sampling Investigation* (MWH 2016). The study designs and applicable datasets for each exposure scenario evaluated in this risk assessment addendum are discussed and presented in Section 3 (woodstove ash

removal) and Section 4 (hooking/skidding). **Figure 2-2** illustrates the ABS areas that were evaluated in 2016.

Since completion of the *Site-wide HHRA* (EPA 2015), risk estimates for each ABS area for these two exposure scenarios were used to inform and delineate the final OU3 boundary (Grace 2017). **Figure 2-2** shows the final OU3 boundary. In this addendum, exposure areas continue to be designated as a function of distance from the mined area, but the areas were modified incorporate the new OU3 boundary. There were three exposure areas evaluated in this HHRA addendum — within the OU3 boundary, outside the OU3 boundary (but within the NPL boundary), and outside the NPL boundary. ABS data from each ABS area were grouped together for the purposes of calculating EPCs for each exposure area.

2.1.5 Exposure Point Concentrations

Predicting the LA levels in air based on measured LA levels in source media is extremely difficult. For this reason, EPA recommends an empiric approach for investigating asbestos-contaminated Superfund sites, where concentrations of asbestos in air from source disturbances are measured rather than predicted (EPA 2008). This type of sampling is referred to as activity-based sampling (ABS). Dozens of ABS investigations have been conducted at the Site to evaluate potential exposures to LA from various disturbances of source media under a wide range of activities. Exposure estimates in the *Site-wide HHRA* were based on more than 3,100 ABS air samples (EPA 2015).

Asbestos data reduction and interpretation methods differ from traditional chemistry methods. Appendix B of the *Site-wide HHRA* (EPA 2015) provided a detailed discussion of basic concepts for asbestos sampling, analysis, and data reduction. All ABS air samples collected in 2016 were analyzed by transmission electron microscopy (TEM). During the analysis, detailed information for each observed asbestos structure (e.g., asbestos type, structure type, length, width) is recorded. For the purposes of computing risk estimates, it is necessary to use the results from the TEM analysis to estimate what would have been detected had the sample been analyzed by phase contrast microscopy (PCM) because available toxicity information is based on workplace studies using PCM as the primary method for analysis. For convenience, structures detected under TEM that meet the recording rules for PCM are referred to as PCM-equivalent (PCME) structures. The TEM counting rules for PCME structures are: length greater than (>) 5 micrometers (μm), width greater than or equal to (≥) 0.25 μm, and aspect ratio (length:width) ≥ 3:1. The upper width cut-off of 3 μm specified by EPA (2008) has not been used, because structures wider than 3 μm are counted by the National Institute of Occupational Safety and Health (NIOSH) PCM method (NIOSH 1994). This basis of this width criterion change was discussed in detail in Appendix C of the *Site-wide HHRA* (EPA 2015). TEM analysis results for air samples are expressed as PCME LA structures per cubic centimeter of air (s/cc).

In accordance with EPA asbestos risk assessment guidance (EPA 2008), EPCs for each exposure area are calculated as the sample mean, evaluating non-detect samples at a concentration value of zero. In cases where air filters required the use of indirect preparation techniques prior to TEM analysis, the reported PCME LA air concentration was adjusted (decreased) by a factor of 2.5 to avoid potentially biasing calculated EPCs high due to the effect of indirect preparation. Appendix D of the *Site-wide HHRA* (EPA 2015) provided detailed site-specific data on the derivation of this indirect preparation adjustment factor.

2.2 Toxicity Assessment

The adverse effects of asbestos exposure in humans have been the subject of many studies and publications. Exposure to asbestos may induce several types of both non-cancer and cancer effects. A detailed summary of the cancer and non-cancer effects of asbestos is provided in the Agency for Toxic Substances and Disease Registry (ATSDR) *Toxicological Profile for Asbestos* (ATSDR 2001) and in EPA's *Airborne Asbestos Health Assessment Update* (EPA 1986). A detailed summary of effects related specifically to LA is provided in the *Toxicological Review of Libby Amphibole Asbestos* (EPA 2014).

2.2.1 Cancer Effects

Many epidemiological studies have reported increased mortality from cancer in workers exposed to asbestos, especially from lung cancer and mesothelioma (tumor of the thin membrane that covers and protects the internal organs of the body). In addition, many studies suggest asbestos exposure may increase risk of cancer of the larynx (commonly called the voice box) and ovarian cancer (IARC 2012). Based on these findings, and supported by extensive data from animal studies, EPA has classified asbestos as a known human carcinogen.

Cancer risk from inhalation exposure is determined based on an inhalation unit risk (IUR) value, which is defined as the excess lifetime cancer risk estimated to result from continuous exposure to one asbestos fiber per cubic centimeter of air (1 f/cc). The LA-specific IUR, referred to as IUR_{LA}, is derived from a group of workers employed at the vermiculite mining and milling operation in and around Libby, referred to as the "Libby worker cohort." The IUR_{LA} is 0.17 (PCM f/cc)$^{-1}$ (EPA 2014).

2.2.2 Non-cancer Effects

Non-cancer effects from asbestos exposure include asbestosis (formation of scar tissue in the lung parenchyma) and several types of abnormalities in the pleura (the membrane surrounding the lungs), such as pleural effusions (excess fluid accumulation in the pleural space), pleural plaques (collagen deposits and calcification), and pleural thickening.

Non-cancer hazard from inhalation exposure is determined based on a reference concentration (RfC) value. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is likely to be without an appreciable risk of deleterious effects in humans (including sensitive subgroups) during a lifetime (EPA 2009). The LA-specific RfC, referred to as RfC_{LA}, is derived from a group of workers employed at the O.M. Scott Plant in Marysville, Ohio. This plant used vermiculite that originated from the mine in Libby from 1959 to 1980 in their lawn care products. Localized pleural thickening was selected as the critical effect endpoint for the derivation of the RfC_{LA}. The RfC_{LA} is 0.00009 PCM f/cc (EPA 2014).

2.3 Risk Characterization

2.3.1 Basic Equations

The basic equation used to estimate excess lifetime cancer risk from inhalation of LA is:

$$Risk = EPC \cdot TWF \cdot IUR_{LA}$$

where:

Risk = Lifetime excess risk of developing cancer (lung cancer or mesothelioma) as a consequence of LA exposure.

EPC = Exposure point concentration of LA in air (PCME LA s/cc). The EPC is an estimate of the long-term average concentration of LA in inhaled air for the specific activity being assessed.

TWF = Time-weighting factor for the specific activity being assessed.

IUR_{LA} = LA-specific inhalation unit risk $(0.17 \text{ PCM s/cc})^{-1}$

The basic equation used for characterizing non-cancer hazards from inhalation exposures to LA is as follows:

$$HQ = EPC \cdot TWF / RfC_{LA}$$

where:

HQ = Hazard quotient for non-cancer effects from LA exposure

EPC = Exposure point concentration of LA in air (PCME LA s/cc)

TWF = Time-weighting factor

RfC_{LA} = LA-specific reference concentration (0.00009 PCM s/cc)

2.3.2 Risk Interpretation

EPA's Office of Solid Waste and Emergency Response (OSWER) Directive #9355.0-30, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (EPA 1991) provides guidance on the interpretation of estimated risks. The level of cancer risk that is of concern is a matter of personal, community, and regulatory judgment. In general, EPA considers cumulative excess cancer risks[4] less than 1E-06 to be negligible and risks greater than 1E-04 to be sufficiently large enough that some form of remedial action is desirable. Excess cancer risks that range between 1E-04 and 1E-06 are generally considered to be acceptable, although this is evaluated on a case-by-case basis, and EPA may determine risks lower than 1E-04 are not sufficiently protective and warrant remedial action.

For non-cancer, if the cumulative HQ (referred to as the hazard index [HI]) is less than or equal to 1, then remedial action is generally not warranted. If the HI exceeds 1, there is some possibility non-cancer effects may occur, although an HI greater than 1 does not indicate an effect will definitely occur. This is because of the margin of safety inherent in the derivation of all toxicity values. However, the larger the HI value, the more likely it is that an adverse effect may occur. Risk management decisions generally consider the sum of all the risks contributed by differing exposure scenarios, rather than simply evaluating each one independently.

As demonstrated in the *Site-wide HHRA*, for a given exposure scenario, non-cancer HQs can exceed 1 even when cancer risks are less than 1E-04, which indicates non-cancer exposure is a more sensitive metric of potential concern (EPA 2015). For LA, a non-cancer HQ of 1 is approximately equivalent to a cancer risk of 1E-05. Thus, risk management decisions will focus on addressing non-cancer hazards, which also will be protective of cancer effects.

[4] Excess cancer risk can be expressed in several formats. A cancer risk expressed in a scientific notation format as 1E-06 is equivalent to 1 in 1,000,000 (one in a million) or 1×10^{-6}. Similarly, a cancer risk of 1E-04 is equivalent to 1 in 10,000 (one in ten thousand) or 1×10^{-4}.

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Section 3

Risks from Exposures to Woodstove Ash

Trial burn experiments in woodstoves (Ward et al. 2009) and in test burn chambers (EPA 2012) indicate the majority of LA structures are retained in the ash when wood and duff materials are burned. Because the LA becomes concentrated in ash, this ash has the potential to be an important source medium for LA exposures. If LA-containing firewood is burned in a residential woodstove, residents may be exposed to LA released to air from the resulting ash during removal of ash from the woodstove.

3.1 Site-wide HHRA Results

In 2012, EPA conducted an ABS study to measure LA concentrations in air during woodstove ash-removal activities (CDM Smith 2012; 2013b). For this study, firewood was collected from dead trees at three locations at varying distances from the mine—near the mine (approximately 1 mile downwind of the mine site), near Flower Creek (approximately 2 miles south of Libby and 9 miles upwind of the mine), and near Bear Creek (approximately 10 miles south of Libby and outside the current NPL boundary). The firewood collected from each location was burned in a woodstove (tree bark was not removed prior to burning). The resulting ash was removed from the woodstove using a long-handled metal shovel and placed into a metal ash bucket (similar to what might be done by a resident). ABS air samples were collected from the breathing zone of the individual conducting the ash removal activity. These ABS air samples were used in the *Site-wide HHRA* to estimate LA exposures and risks from this exposure scenario.

Risks associated with the removal of ash from a woodstove differed depending on the source of the firewood burned (see **Table 3-1**). If firewood was collected from a location near the mine (about 1 mile from the mine where tree bark LA levels are highest), the RME non-cancer HQ for LA exposures during ash removal activities was 2. However, if firewood was collected from locations far from the mine (2–10 miles south of Libby), HQs were less than 0.1. These risk estimates demonstrated woodstove ash may be an important source medium, if the ash is derived from a wood source near the mine.

3.2 Data Summary for 2016 Investigation

In the summer of 2016, an ABS study was conducted to further evaluate potential residential exposures during woodstove ash-removal activities (MWH 2016). In particular, this study was designed to specifically address two data limitations related to this exposure scenario noted in the *Site-wide HHRA*. First, there were no ABS air data that provided information on potential exposures during woodstove ash-removal activities when firewood was collected at locations downwind from the mine at distances beyond 1 mile or in locations upwind/crosswind of the mine. Second, although it was presumed the LA in the ash is likely to be derived from fibers on the outer bark surface of the collected firewood, there were no data that provided information on differences in LA content of outer bark and "inner wood" (hereafter referred to as wood).

A summary of the woodstove ash ABS activities is presented below. Specific investigation-design information is included in the *Sampling and Analysis Plan/Quality Assurance Project Plan: 2016 Woodstove Ash and Hooking/Skidding Activity Based Sampling Investigation* (MWH 2016) and the *QAPP*

Addendum (Record of Modification LFM-OU3-01): Pilot Study to Compare LA Levels in Bark and Wood, Operable Unit 3, Libby Asbestos Superfund Site (CDM Smith 2016a). **Appendix A** provides the detailed analytical results for all ABS air samples used in this HHRA addendum. **Appendix B** provides a data quality assessment of the datasets used to calculate EPCs and estimate risks in this HHRA addendum.

3.2.1 ABS Air During Woodstove Ash Removal Activities

A total of nine firewood collection locations (ABS Areas A through I) were selected for evaluation in the 2016 study (**Figure 2-2**). These areas were selected because they represented a range of LA levels on tree bark and were spatially arrayed within the OU3 Study Area[5] to support the delineation of a risk-based OU3 boundary. In **Figure 2-2**, the “near the mine” woodstove ash location evaluated as part of the *Site-wide HHRA* is shown as a yellow triangle[6]. The two other locations—"near Flower Creek” and “near Bear Creek,” which are located approximately 2–10 miles south of Libby—are outside the map extent and are not shown.

To ensure comparability with the original 2012 woodstove ash study (described in Section 3.1), the 2016 ABS activities and sampling methods mimicked what was done in 2012. In brief, at each of the nine ABS areas, two standing deadwood Douglas fir trees with intact bark were identified for use in the woodstove ash ABS study. The two trees were felled, sawed to length, and split to generate firewood for use in the woodstoves. The firewood collected from each ABS area was burned in a dedicated woodstove (tree bark was not removed prior to burning). The resulting ash was removed from the woodstove using a long-handled metal shovel and placed into a metal ash bucket (similar to what might be done by a resident). ABS air samples were collected from the breathing zone of the individual conducting the ash removal activity. Three 10-minute sampling events were conducted for each firewood collection location (changing out the filter every 5 minutes).

Table 3-2 (Panel A) presents summary statistics of the measured ABS air concentrations for each firewood collection location (ABS area). These data were used to estimate exposures to residents from inhalation of LA during woodstove ash-removal activities.

3.2.2 Inner Wood versus Outer Bark

Extensive data on LA levels on the bark surface of trees and in duff materials have been collected in the forested area near the mine (CDM Smith 2016b) and near the NPL boundary (CDM Smith 2013a). These data show LA fibers are present on the outer bark surface of trees and in duff material at the Site. In general, LA levels in bark and duff tend to be highest closest to the mine (within about 3–4 miles), but LA fibers have been detected in bark and duff 13 or more miles from the mine (CDM Smith 2013a).

Prior to 2016, data collection efforts had focused solely on the measurement of surface loading levels on the outer surface of the trees (i.e., the bark), based on the presumption the primary mechanism of LA transport is via airborne dispersion and deposition onto the outer surface of the bark. However, there were no measured data on the potential LA content of the wood of the tree (i.e., underneath the bark) to support the assumption that bark contamination is higher than wood contamination. Because it is possible future remedial alternatives may include debarking requirements to mitigate potential

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[5] EPA established a preliminary study area for the purposes of study planning and developing the OU3 RI. The final OU3 boundary was delineated in 2017 (following the completion of the 2016 ABS investigation) (Grace 2017). **Figure 2-2** shows both the OU3 Study Area and the final OU3 boundary.

[6] This triangle area is also referred to as “Area 1” in the Section 3 tables.

LA exposures from woodstove ash derived from locally collected firewood, LA concentrations for wood samples were measured to determine if debarked firewood would have lower levels of LA contamination.

During the pilot study, wood samples were collected from the same nine ABS areas investigated as part of the woodstove ash study described above. As noted above, at each ABS area, two standing deadwood Douglas fir trees with intact bark were identified for use in the woodstove ash ABS study. A clean chisel was used to remove the bark from a small area to allow for the collection of a wood core (sans bark). For each ABS area, a total of five wood cores were collected across the two selected trees at varying heights and composited into a single sample. After the wood samples were collected, the two trees were felled, sawed to length, and split to generate firewood for use in the woodstoves. Prior to burning the firewood, four composite bark samples were collected for each ABS area, with each composite consisting of five individual bark cores. The wood core sample and bark samples from each ABS area were analyzed for LA by TEM.

Table 3-3 summarizes the average LA concentrations, expressed as million structures of LA per gram (dry weight) (Ms/g), for the inner wood and outer bark samples for each ABS area. In this table, concentrations based on total LA (i.e., LA structures with a length ≥ 0.5 um and an aspect ratio ≥ 3:1) are presented in Panel A and concentrations based on PCME LA (i.e., LA structures with length > 5 µm, width ≥ 0.25 µm, and aspect ratio ≥ 3:1) are presented in Panel B. Results based on total LA are most relevant for the purposes of informing nature and extent of contamination, whereas results based on PCME LA are representative of the structure size classification of potential health concern (see Section 2.1.5).

Total LA structures were observed in bark samples from all nine ABS areas, with average concentrations ranging from 0.023 to 2.4 Ms/g. Most of the wood samples (7 of 9 samples) were reported as non-detect for total LA; when LA was detected, wood concentrations were lower than the corresponding bark concentrations. For all ABS areas, the total LA bark sample concentration was higher than the corresponding wood sample concentration. Similar results were also noted based on PCME LA structures. When bark and wood concentrations were compared using the Poisson ratio comparison test (Nelson 1982), the difference in total LA concentrations was statistically significant for 5 of the 9 samples (i.e., the difference in concentrations is more than would be expected as a consequence of analytical uncertainty due to Poisson counting error).

These results support the conclusion that the primary mechanism by which tree bark becomes contaminated with LA is via airborne dispersion and deposition onto the outer surface of the bark. These results also indicate debarking of firewood prior to burning would likely reduce potential PCME LA exposures during woodstove ash removal activities.

3.3 Exposure Point Concentrations

Previous investigations conducted at the Site have demonstrated LA concentrations in soil and duff in the forest areas surrounding the mine tend to be highest near the mine site and decrease as a function of distance from the mine (CDM Smith 2016b). As described in Section 2.1.4, EPCs were calculated for three exposure areas—within the OU3 boundary (see **Figure 2-2**), outside the OU3 boundary (but within the NPL boundary), and outside the NPL boundary. ABS data from each ABS area (see **Figure 2-2**) were grouped together for the purposes of calculating EPCs for each exposure area.

Table 3-2 (Panel B) presents summary statistics of the measured ABS air concentrations for each exposure area. The mean air concentration for each exposure area was used as the EPC in the risk calculations.

3.4 Exposure Population and Parameters

As noted previously, exposure parameters are determined for representative members of the exposure population, to estimate exposures based on those with typical levels of exposure (CTE) and those with high-end exposures (RME). **Table 3-4** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential residential exposures during woodstove ash disturbance activities. These exposure parameter values are the same as those used in the *Site-wide HHRA* (EPA 2015).

3.5 Risk Estimates

Table 3-5 presents estimated cancer risks and non-cancer HQs from exposures during woodstove ash disturbance activities based on RME (Panel A) and CTE (Panel B). The estimated RME and CTE cancer risks are less than 1E-05 and non-cancer HQs are less than 1 for all three exposure areas. Estimated risks are highest within the OU3 boundary, which encompasses the former mine and surrounding forested area (see **Figure 2-2**). This is generally consistent with the spatial patterns of LA contamination in tree bark, which also tend to be highest near the mine and lowest farther from the mine.

Table 3-6 presents estimated RME cancer risks and non-cancer HQs from exposures during woodstove ash disturbance activities on an ABS area-specific basis. These calculations illustrate how exposures and risks vary on a smaller scale than the exposure areas presented in **Table 3-5**. As shown, there is only one ABS area (Area 1; the triangle area located approximately 1 mile from the mine in the downwind location in **Figure 2-2**) with a non-cancer HQ greater than 1. These results suggest that, outside of this limited area, exposures from the use of LA-contaminated firewood are not likely to be of potential concern and this exposure scenario would not be expected to contribute significantly to cumulative risks.

Section 4

Risks from Exposures During Soil/Duff Disturbances

The *Site-wide HHRA* evaluated a wide range of potential exposure scenarios across each of the eight OUs (EPA 2015). Since the completion of the HHRA, additional data have been collected to further characterize potential exposures and risks for OU3 (no additional data have been collected for other OUs in support of further risk characterization). OU3 includes the property in and around the former vermiculite mine and the geographic area surrounding the mine that has been impacted by releases and subsequent migration of contaminants from the mine, including several ponds, creeks, and Rainy Creek Road. Most of the land in OU3 is forested and characterized by steep and rugged terrain. Much of the land surrounding the mine is managed by the U.S. Forest Service (USFS), although some parcels are owned by the State of Montana and are managed by the Department of Natural Resources and Conservation.

4.1 Site-wide HHRA Results

A range of different human receptor populations may be exposed to LA in OU3, including trespassers (or "rockhounds") in the mined area, recreational visitors in the forested area and along area creeks and ponds, and USFS forest maintenance workers and firefighters, local wood harvesters, and commercial loggers in the forested area surrounding the mine. **Table 4-1** summarizes the estimated RME cancer risks and non-cancer HQs from exposures to LA during various exposure scenarios related to OU3 as presented in the *Site-wide HHRA* (EPA 2015). As shown, there were very few exposure scenarios that, when considered alone, yielded RME non-cancer HQs that exceeded 1. The exposure scenarios exceeding a non-cancer HQ of 1 are listed below:

- Outdoor worker exposures during commercial logging activities in OU3 near the mine, especially those logging activities that disturb soil and duff material (e.g., hooking/skidding, site restoration) (HQ = 5 for hooking/skidding; HQ = 2 for site restoration)
- Firefighter exposures while performing mop-up activities after an understory burn that occurred near the mine (HQ = 5 for dry mop-up)
- Forest worker exposures while building slash piles near the mine (HQ = 2)
- Rockhound exposures in the disturbed area of the mine (HQ = 2)
- Residential exposures during woodstove ash disturbances[7] when firewood is collected near the mine (HQ = 2)

There were also several exposure scenarios that, when considered alone, yielded RME non-cancer HQs that approached or equaled 1 (e.g., firefighter exposures during an understory burn and during wet mop-up activities after an understory burn). Although these exposure scenarios alone do not result in unacceptable risks, they have the potential to be important contributors to cumulative risk.

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[7] This exposure scenario was discussed in Section 3.

4.2 Data Summary for 2016 Investigation

In the summer of 2016, an ABS study was conducted to further evaluate potential exposures during soil/duff disturbance activities in the forested areas in OU3 (MWH 2016). As noted above, there were several exposure scenarios with RME non-cancer HQs above (or approaching) 1. The two exposure scenarios that resulted in the highest non-cancer HQs were during hooking/skidding (i.e., dragging felled logs across the ground) and during dry mop-up activities following an understory burn (i.e., using a Pulaski axe to mix, stir, and dig up the mineral soil to address any remaining "hot spots" without the application of water); both scenarios had HQs of 5 (**Table 4-1**). Of these two scenarios, the hooking/skidding scenario was selected as the target soil/duff disturbance activity for the 2016 ABS investigation because it yielded a non-cancer HQ similar to the dry mop-up and could be readily conducted across multiple locations throughout the forest without concern of potentially sparking unintentional forest fires.

The hooking/skidding scenario was intended to be a surrogate soil/duff disturbance activity that would be representative of potential HQs for an understory burn dry mop-up scenario. In other words, for a particular ABS area, if the non-cancer HQ was 3 for hooking/skidding, it is assumed the non-cancer HQ would also be (approximately) 3 for an understory burn dry mop-up scenario within this ABS area. It also is assumed other high intensity soil/duff disturbance exposure scenarios of potential interest for OU3 with HQs less than 5 (**Table 4-1**) (e.g., site restoration following logging, building slash piles, understory wet mop-up) would have estimated HQs lower than hooking/skidding.

Specific investigation-design information is included in the *Sampling and Analysis Plan/Quality Assurance Project Plan: 2016 Woodstove Ash and Hooking/Skidding Activity Based Sampling Investigation* (MWH 2016) and is described briefly below. **Appendix A** provides the detailed analytical results for all ABS air samples used in this HHRA addendum. **Appendix B** provides a data quality assessment of the datasets used to calculate EPCs and estimate risks in this HHRA addendum.

Eight[8] ABS areas were selected for evaluation in this study (**Figure 2-2**). These areas were selected because they represented a range of potential LA levels in soil/duff and were spatially arrayed within the OU3 Study Area to support the delineation of a risk-based OU3 boundary. **Figure 2-2** also shows the location of the two commercial logging ABS areas[9] evaluated as part of the *Site-wide HHRA*.

For each of the eight ABS areas, the area was divided into four approximately equal subsections and a five-point composite sample of duff material was collected from each subsection prior to conducting ABS activities. In addition, several (one to five trees) were felled for each ABS area for use in hooking/skidding activities (felled trees were not delimbed prior to hooking/skidding). During the simulated hooking/skidding ABS activity, a skidder operator would attach (hook) cables to a felled tree and then drag (skid) the tree across the ABS area, exiting the cab at regular intervals to unhook/hook each tree for a total duration of about 2.5 hours (changing out the filter every 30 minutes).

Table 4-2 (Panel A) presents summary statistics of the measured ABS air concentrations for each ABS area. These data were used to estimate exposures to LA from hooking/skidding activities.

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[8] ABA Area I was evaluated only as part of the woodstove ash removal ABS study; hooking/skidding ABS activities were not performed in this area.
[9] These ABS locations are referred to as Area 1 (~1 mile from mine) and Area 2 (~4 miles from mine) in the Section 4 tables.

4.3 Exposure Point Concentrations

As described in Section 2.1.4, EPCs were calculated for three exposure areas—within the OU3 boundary (see **Figure 2-2**), outside the OU3 boundary (but within the NPL boundary), and outside the NPL boundary. ABS data from each ABS area (see **Figure 2-2**) were grouped together for the purposes of calculating EPCs for each exposure area.

Table 4-2 (Panel B) presents summary statistics of the measured ABS air concentrations for each exposure area. The mean air concentration for each exposure area was used as the EPC in the risk calculations.

4.4 Exposure Population and Parameters

As noted previously, exposure parameters are determined for representative members of the exposure population, to estimate exposures based on those with typical levels of exposure (CTE) and those with high-end exposures (RME). **Table 3-4** presents the selected RME and CTE exposure parameter values and calculated TWFs for evaluating potential exposures during hooking/skidding activities. These exposure parameter values are the same as those used in the *Site-wide HHRA* (EPA 2015).

4.5 Risk Estimates

Table 4-3 presents estimated cancer risks and non-cancer HQs from exposures to LA during hooking/skidding activities based on RME (Panel A) and CTE (Panel B). These results indicate that, when this exposure scenario is considered alone, estimated RME and CTE cancer risks are less than 1E-04, but RME non-cancer HQs are greater than 1 when hooking/skidding activities are performed within the OU3 boundary. When hooking/skidding activities are performed outside the OU3 boundary estimated cancer risks are less than 1E-06 and non-cancer HQs are less than 0.1 for both RME and CTE.

Table 4-4 presents estimated RME cancer risks and non-cancer HQs from exposures during hooking/skidding activities on an ABS area-specific basis. These calculations illustrate how exposures and risks vary on a smaller scale than the exposure areas presented in **Table 4-3**. As shown, estimated cancer risks are less than 1E-04 for all ABS areas. However, estimated non-cancer HQs exceed or approach 1 for most ABS areas within the OU3 boundary. Outside the OU3 boundary, non-cancer HQs are at or below 0.2 for all ABS areas.

4.5.1 Extrapolation to Other Soil/Duff Disturbance Scenarios

The two exposure scenarios for OU3 that resulted in the highest non-cancer HQs were during hooking/skidding activities and during dry mop-up activities following an understory burn; both scenarios had HQs of 5. As noted above, the hooking/skidding scenario was selected as a surrogate soil/duff disturbance activity and intended to be representative of potential HQs for an understory burn dry mop-up scenario. It is assumed other high intensity soil/duff disturbance exposure scenarios of potential interest for OU3, which had HQs less than 5 (**Table 4-1**), would have estimated HQs lower than hooking/skidding. Thus, if risk management decisions are based on hooking/skidding, these decisions would be adequately protective of all soil/duff disturbance scenarios in the forest in OU3.

4.5.2 Extrapolation to Areas Without ABS

OU3 encompasses approximately 10,000 acres of forest, and it is not feasible to evaluate risks by conducting ABS throughout this entire area. Thus, it is necessary to use data from ABS areas that have been investigated to draw risk conclusions about areas that have not been studied by ABS. There is a general relationship between LA levels in source media and airborne concentrations of LA during ABS activities when evaluated on a larger scale (i.e., both source media levels and air concentrations of LA generally tend to decrease as distance from the mine increases). Although it was hoped data from the 2016 ABS investigation could be used to perform a regression analysis between LA levels in duff and LA concentrations in ABS air, measured data did not yield a meaningful correlation when evaluated on an ABS area-basis using the co-located data collected in 2016.

Because it was anticipated a regression analysis may not be possible, when planning the 2016 ABS investigation, the ABS areas were placed in locations downwind, upwind, and crosswind from the mine, and spaced so that ABS data were collected at varying distances from the mine. This ABS area spacing helped to refine the pattern and extent of risks and bound the spatial extent of potential unacceptable risks. The final OU3 boundary was delineated in 2017 following the completion of the 2016 ABS investigation and evaluation of the ABS area risk estimates (Grace 2017). **Figure 2-2** illustrates the final OU3 boundary (see blue outline).

For locations where ABS activities have not been conducted, it is assumed potential LA exposures and risks would be similar to nearby ABS areas. However, it is recognized that actual risks may vary spatially, given the spatial patterns in LA contamination and the fact that forest exposure scenarios, such as hooking/skidding and firefighting, may not occur uniformly across the landscape.

Section 5
Uncertainty Assessment

As with all HHRAs, uncertainties exist due to limitations in the exposure and toxicity assessments and our ability to accurately determine cumulative exposure and risk from multiple sources over a lifetime. This risk assessment has used the best available science to evaluate potential human health exposures and risks from LA in OU3. However, there are many sources of uncertainty that affect the risk estimates that must be considered when making risk management decisions. The most important of these sources of uncertainty are listed below and are discussed in detail in Section 10 of the *Site-wide HHRA* (EPA 2015).

1) Uncertainty in true long-term average LA concentrations in air
2) Uncertainty in the EPC due to non-detects
3) Uncertainty due to air filter preparation methods
4) Uncertainty due to analytical methods
5) Uncertainty due to field collection methods
6) Uncertainty in human exposure patterns
7) Uncertainty in toxicity values used in risk characterization

Because of these uncertainties, the cancer risks and non-cancer HQs for individual exposure scenarios are uncertain and should be considered approximations. As discussed in Section 10 of the *Site-wide HHRA* (EPA 2015), the first five of these sources of uncertainty are due to inherent variability, sampling uncertainty, or collection procedures. In accordance with EPA guidance (EPA 2008), the most practical methods have been used to minimize uncertainty associated with these sources. Risk management decision-making is based on estimated exposures and risks derived from RME exposure parameters (EPA 1991), which are intended to represent members of the population with high-end exposures, to ensure decisions are sufficiently protective of the general population. RME exposure parameters were chosen in a way that is intended to be conservative. Therefore, the selected RME values are likely to overestimate actual exposure. Similarly, the toxicity values used in risk characterization were derived in a way that is intended to be conservative and are more likely to overestimate than to underestimate true risks.

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Section 6

Risk Assessment Conclusions

This risk assessment addendum characterizes risks to people from exposure to LA in the forested areas at the Site to help risk managers determine if remedial actions are necessary to address risks and, if so, which exposure scenarios and locations would need to be addressed in future remedial actions. Results of this risk assessment addendum are intended to help inform Site managers and the public about the magnitude of potential risks attributable to LA and to guide the selection of final remedial actions for OU3.

Since completion of the *Site-wide HHRA* (EPA 2015), additional exposure data were collected in 2016 to evaluate two exposure scenarios of interest for OU3: 1) residential exposures during woodstove ash disturbances (i.e., while emptying ash from the woodstove) when firewood is collected locally, and 2) outdoor worker exposures during soil/duff disturbances associated with commercial logging activities. Risk estimates for these two exposure scenarios were evaluated in Section 3 and Section 4 of this addendum, respectively, and are summarized below. Because the non-cancer endpoint is the more sensitive metric of potential concern for LA, the risk discussion below focuses on RME non-cancer HQs.

6.1 Risks from Exposures to Woodstove Ash

RME non-cancer HQs are less than 1 for all the exposure areas evaluated (**Table 3-5**). The HQ was highest within the OU3 boundary (HQ = 0.5) and decreased with increasing distance from the mine. However, inspection of the ABS area-specific risk estimates (**Table 3-6**) shows that, outside of a limited area, located approximately 1 mile downwind from the mine (i.e., the Area 1 triangle in **Figure 2-2**), exposures from the use of LA-contaminated firewood are not likely to be of potential concern and this exposure scenario would not be expected to contribute significantly to cumulative risks.

6.2 Risks from Exposures During Soil/Duff Disturbances

RME non-cancer HQs are greater than 1 when hooking/skidding activities are performed within the OU3 boundary (**Table 4-3**). Inspection of the ABS area-specific risk estimates (**Table 4-4**) shows non-cancer HQs have the potential to exceed or approach 1 throughout most of the OU3 boundary, with the highest HQ in an area located approximately 1 mile downwind from the mine (i.e., the Area 1 triangle in **Figure 2-2**). Outside the OU3 boundary, non-cancer HQs are at or below 0.2 for all ABS areas.

The hooking/skidding scenario was selected as a surrogate exposure scenario for soil/duff disturbance activities. Potential risks for other soil/duff disturbance exposure scenarios of potential interest for OU3 (e.g., understory mop-up, site restoration following logging, and building slash piles) should be similar to or lower than hooking/skidding. Thus, if risk management decisions are based on hooking/skidding results, these decisions should be adequately protective of all soil/duff disturbance exposure scenarios in the forested areas in OU3.

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Section 7

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Figures

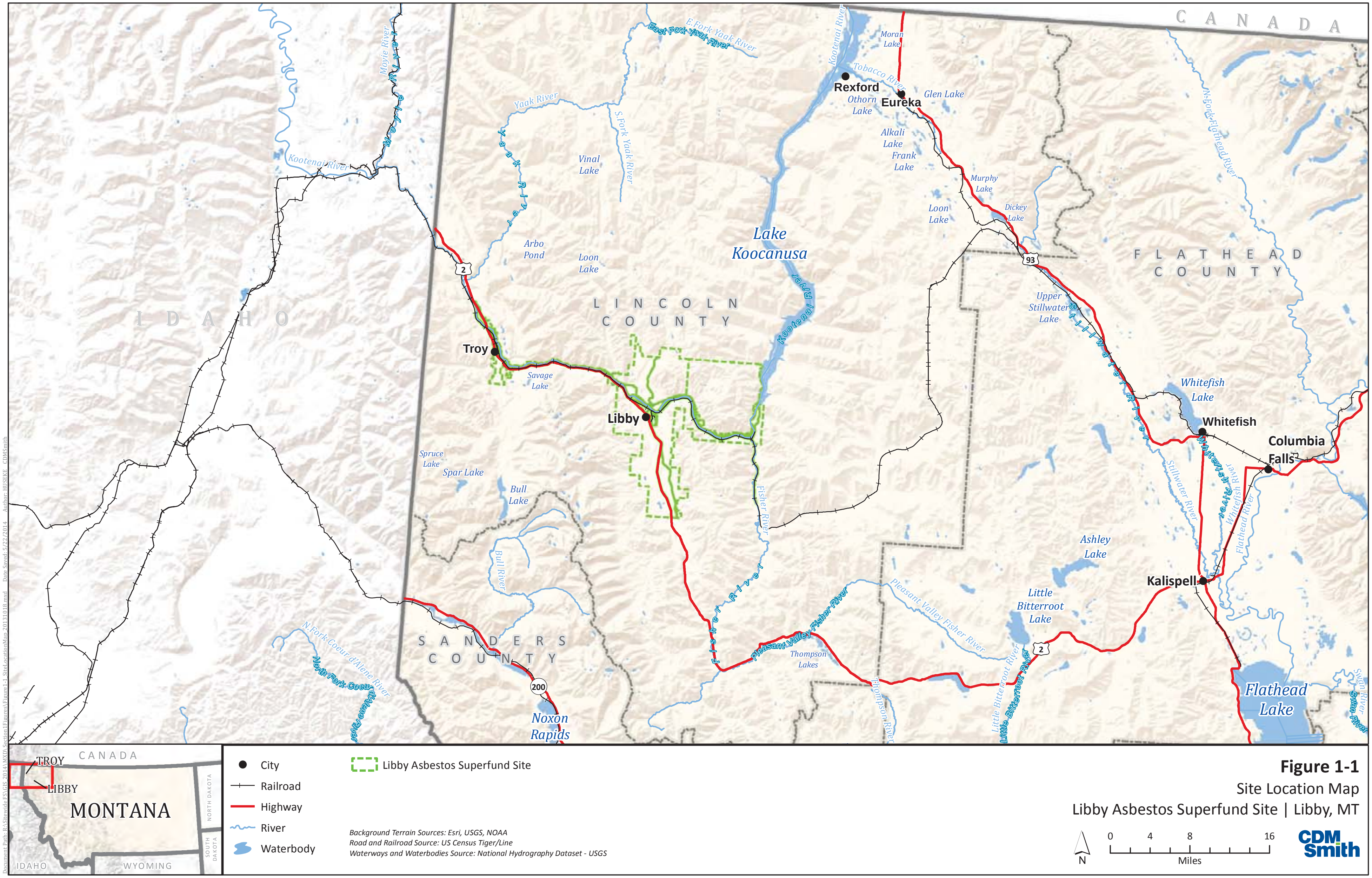


Figure 1-1
Site Location Map
Libby Asbestos Superfund Site | Libby, MT

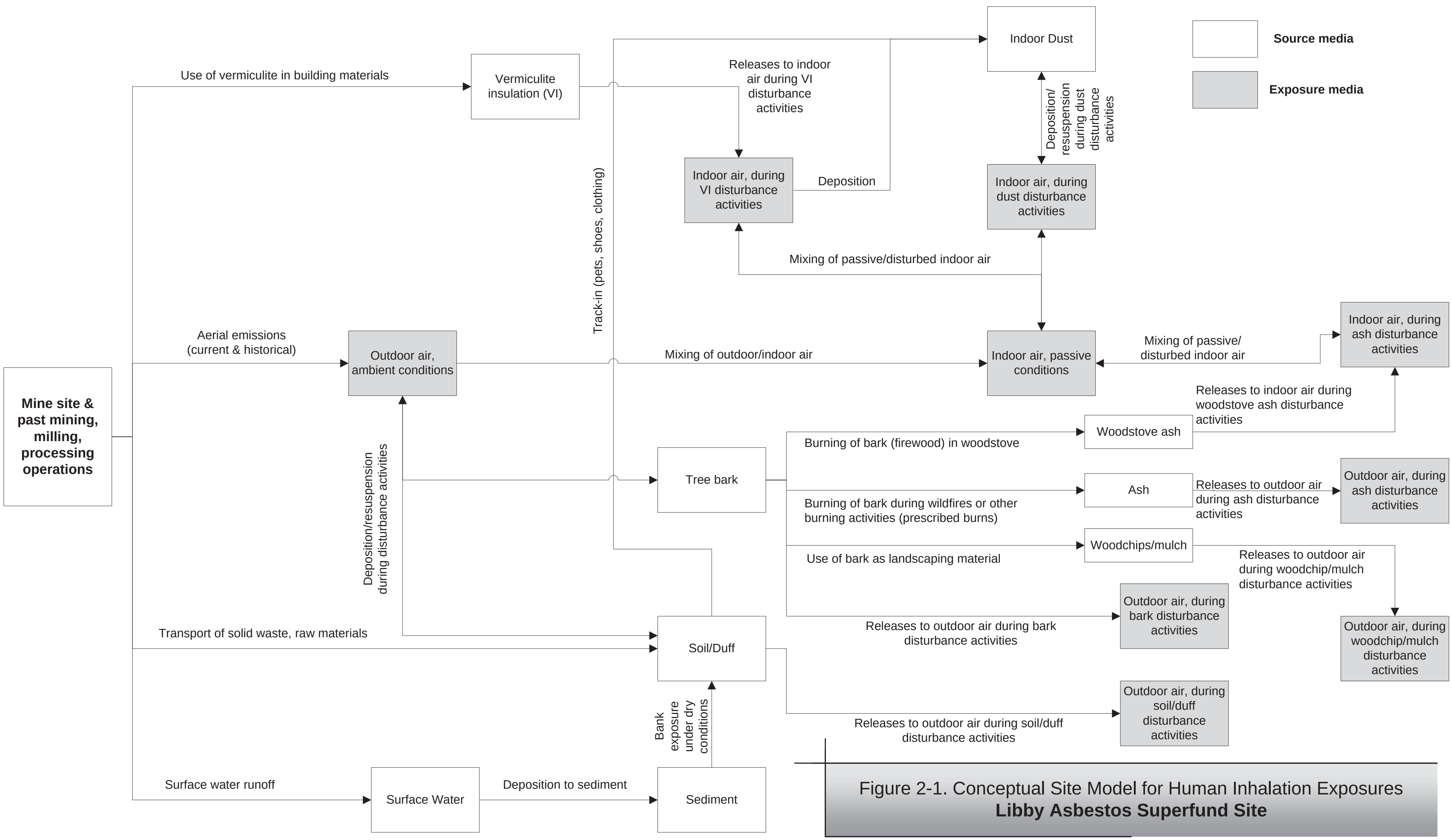
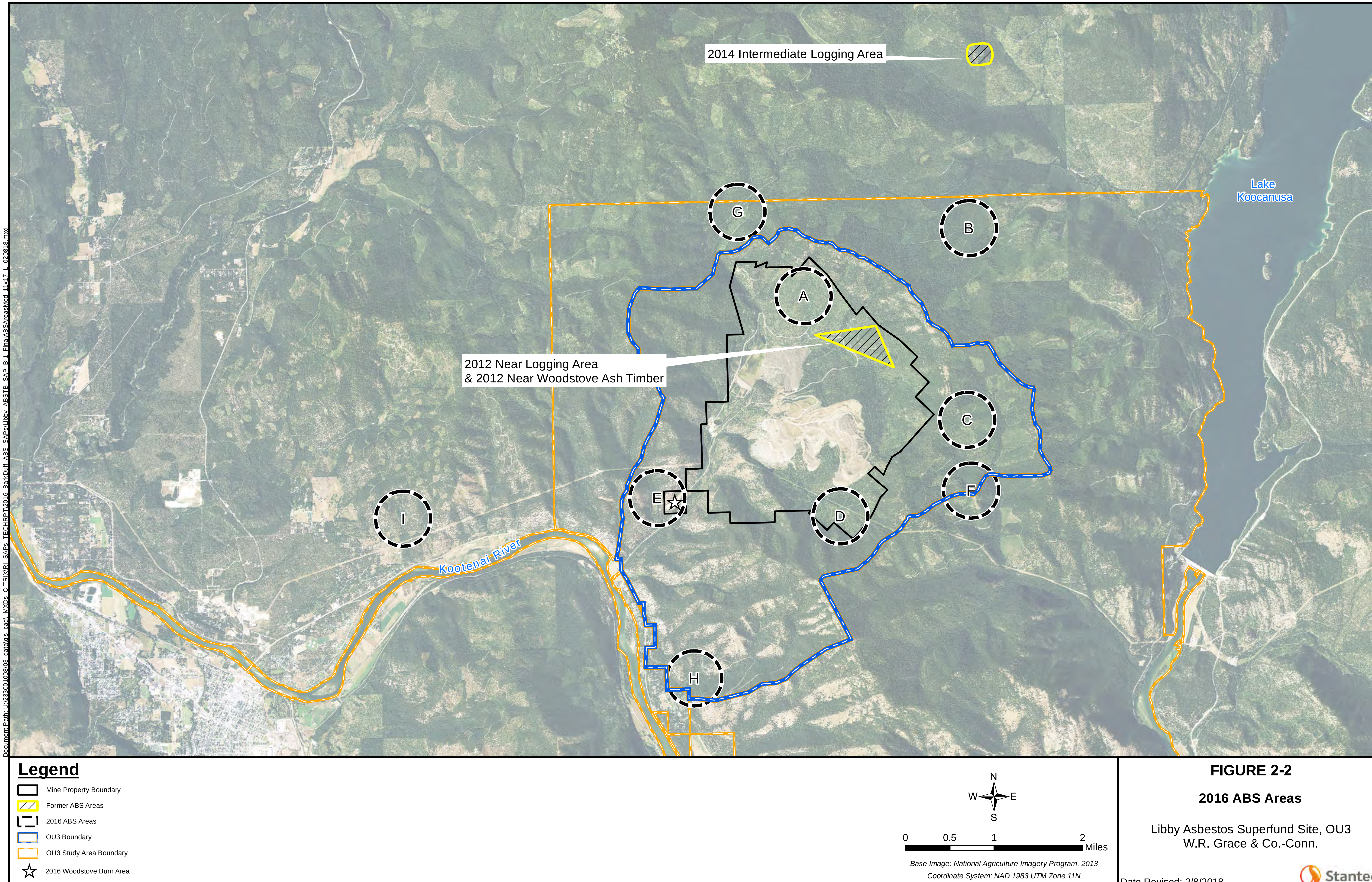


Figure 2-1. Conceptual Site Model for Human Inhalation Exposures
Libby Asbestos Superfund Site


2014 Intermediate Logging Area
Lake Koocanusa
G
B
A
2012 Near Logging Area
& 2012 Near Woodstove Ash Timber
C
E
F
D
I
Kootenai River
H
Legend
Mine Property Boundary
Former ABS Areas
2016 ABS Areas
OU3 Boundary
OU3 Study Area Boundary
2016 Woodstove Burn Area
N
W
E
S
0 0.5 1 2 Miles
Base Image: National Agriculture Imagery Program, 2013
Coordinate System: NAD 1983 UTM Zone 11N
FIGURE 2-2
2016 ABS Areas
Libby Asbestos Superfund Site, OU3
W.R. Grace & Co.-Conn.
Date Revised: 2/8/2018
Stantec

Tables

TABLE 3-1 ESTIMATED RME RISKS FROM EXPOSURES TO LA DURING WOODSTOVE ASH REMOVAL ACTIVITIES AS PRESENTED IN THE SITE-WIDE HHRA

Libby Asbestos Superfund Site

Exposure Area	ABS Area	Mean EPC+ (PCME LA s/cc)	Based on RME Parameters					
			Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Near	Near Mine	0.14	0.25	48	52	0.0010	**2E-05**	**2**
Intermediate	*No data collected for this scenario in this exposure area*							
Far	Near Flower Creek	0.0074	0.25	48	52	0.0010	**1E-06**	**0.08**
	Near Bear Breek	0.0029	0.25	48	52	0.0010	**5E-07**	**0.03**

Source: Table 8-5 (Panel A) in the *Site-wide HHRA* (EPA 2015)

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

HQ > 1

Distances from the mine are defined as follows:

Near: within two miles from the mine

Intermediate: between two and six miles from the mine

Far: more than six miles from the mine

Notes:

EPC = exposure point concentration

HQ = hazard quotient

LA = Libby amphibole asbestos

PCME = phase contrast microscopy equivalent

s/cc = structures per cubic centimeter

TABLE 3-2 SUMMARY STATISTICS FOR ABS AIR SAMPLES COLLECTED DURING WOODSTOVE ASH DISTURBANCES

Libby Asbestos Superfund Site

Panel A: Summary Statistics for each ABS Area

Exposure Area*	ABS Area	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
				Mean	Maximum	
Within OU3 Boundary	Near Mine (Area 1)	3	3	0.14	0.34	0.013
	Area A	6	5	0.029	0.053	0.012
	Area C	6	4	0.032	0.10	0.014
	Area D	6	3	0.015	0.036	0.012
	Area E	6	2	0.038	0.20	0.015
	Area F	6	1	0.0057	0.034	0.015
	Area H	6	2	0.0084	0.033	0.014
Outside OU3 Boundary	Area B**	6	3	0.015	0.035	0.015
	Area G	6	0	0	0	0.015
	Area I	6	1	0.0090	0.054	0.015
	Near Flower Creek	3	3	0.0074	0.018	0.0056
Outside NPL Boundary	Near Bear Creek	3	1	0.0029	0.0087	0.013

Original ABS areas evaluated in the *Site-wide HHRA* (EPA 2015)

Panel B: Summary Statistics for each Exposure Area

Exposure Area*	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Within OU3 Boundary	39	20	0.038	0.34	0.014
Outside OU3 Boundary	21	7	0.0079	0.054	0.013
Outside NPL Boundary	3	1	0.0029	0.0087	0.013

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

*Exposure Areas:

Within OU3 Boundary: includes ABS Areas A, C, D, E, F, H, and "Near Mine" (aka Area 1)
Outside OU3 Boundary: includes ABS Areas B**, G, I and "Near Flower Creek"
Outside NPL Boundary: includes "Near Bear Creek"

**The firewood collection location for ABS Area B was slightly outside of the NPL boundary; however, for the purposes of the risk estimates, this area was included in the "Outside of OU3 Boundary" grouping

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
PCME - phase contrast microscopy equivalent
s/cc - structures per cubic centimeter

TABLE 3-3 COMPARISON OF TOTAL LA CONCENTRATIONS IN WOOD AND BARK

Libby Asbestos Superfund Site

Panel A: Based on Total LA[1]

Exposure Area*	ABS Area	Tree Bark[2]			Wood			Ratio Bark: Wood	Poisson Ratio Comparison Test (90% CI) [Rate 1 = Bark; Rate 2 = Wood]
		No. Total LA Structures Observed	Achieved Sensitivity (1/g)	Total LA Conc. (Ms/g, dw)	No. Total LA Structures Observed	Achieved Sensitivity (1/g)	Total LA Conc. (Ms/g, dw)		
Within OU3 Boundary	Area A	94	3E+04	2.4	0	3E+04	0	---	[0-0.04] Rate 1 is greater than Rate 2
	Area C	37	3E+04	1.0	0	4E+03	0	---	[0-0.01] Rate 1 is greater than Rate 2
	Area D	10	2E+04	0.16	2	3E+04	0.060	2.7	[0.7-17.35] The rates are not different
	Area E	25	2E+04	0.44	1	1E+04	0.011	40	[7.73-801.15] Rate 1 is greater than Rate 2
	Area F	5	2E+04	0.095	0	4E+04	0	---	[0-1.87] The rates are not different
	Area H	2	1E+04	0.023	0	1E+05	0	---	[0-34.47] The rates are not different
Outside OU3 boundary	Area B	12	4E+04	0.47	0	1E+05	0	---	[0-0.7] Rate 1 is greater than Rate 2
	Area G	21	2E+04	0.48	0	3E+04	0	---	[0-0.18] Rate 1 is greater than Rate 2
	Area I	6	2E+04	0.14	0	3E+05	0	---	[0-6.95] The rates are not different

Panel B: Based on PCME LA[1]

Exposure Area*	ABS Area	Tree Bark[2]			Wood			Ratio Bark: Wood	Poisson Ratio Comparison Test (90% CI) [Rate 1 = Bark; Rate 2 = Wood]
		No. PCME LA Structures Observed	Achieved Sensitivity (1/g)	PCME LA Conc. (Ms/g, dw)	No. PCME LA Structures Observed	Achieved Sensitivity (1/g)	PCME LA Conc. (Ms/g, dw)		
Within OU3 Boundary	Area A	14	3E+04	0.36	0	3E+04	0	---	[0-0.28] Rate 1 is greater than Rate 2
	Area C	8	3E+04	0.23	0	4E+03	0	---	[0-0.07] Rate 1 is greater than Rate 2
	Area D	6	2E+04	0.10	0	3E+04	0	---	[0-1.19] The rates are not different
	Area E	2	2E+04	0.04	1	1E+04	0.011	3.2	[0.25-91.74] The rates are not different
	Area F	3	2E+04	0.057	0	4E+04	0	---	[0-3.9] The rates are not different
	Area H	1	1E+04	0.012	0	1E+05	0	---	[0-188.63] The rates are not different
Outside OU3 boundary	Area B	0	4E+04	0	0	1E+05	0	---	Both counts are 0; the rates are not different
	Area G	4	2E+04	0.092	0	3E+04	0	---	[0-1.31] The rates are not different
	Area I	0	2E+04	0	0	3E+05	0	---	Both counts are 0; the rates are not different

[1] Total LA: Structures with a length ≥ 0.5 um and an aspect ratio ≥ 3:1

PCME LA: Structures with a length > 5 um, width ≥ 0.25 um, and an aspect ratio ≥ 3:1

[2] Pooled results across 4 bark samples; expressed as concentration, not surface loading

--- = not calculated; wood concentration was non-detect

Notes:
1/g = per gram
ABS - activity-based sampling
CI = confidence interval
Conc. - concentration
LA - Libby amphibole asbestos
Ms/g, dw - million structures per gram (dry weight)
No. - number
PCME - phase contrast microscopy equivalent

*Exposure Areas:
Within OU3 Boundary: includes ABS Areas A, C, D, E, F, and H
Outside OU3 Boundary: includes ABS Areas B, G, and I

TABLE 3-4 EXPOSURE PARAMETERS FOR EXPOSURE SCENARIOS EVALUATED IN THE HHRA ADDENDUM
Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Parameter Type	Exposure Parameters						
			Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
			Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Resident	Woodstove Ash Removal	RME	0.25	[2] a	48	[2] c	52	[4] f	0.0010
		CTE	0.25	[2] a	24	b	22	[4] f	0.00022
Outdoor Worker	Commercial Logging - hooking/skidding	RME	10	[1]	24	[1] d	12	[3]	0.0047
		CTE	8	[1]	8	[1] e	12	[3]	0.0013

** TWF calculated as ET/24 · EF/365 · ED/70

<u>Source Citations:</u>

[1] Personal communication with United States Forest Service (USFS); email dated 6/24/14.
[2] Interviews with residents that use wood-burning stoves for home heating (CDM Smith. 2012. *Sampling and Analysis Plan/Quality Assurance Plan: Wood-Burning Stove Ash Removal Activity-Based Sampling, Libby Asbestos Site, Operable Unit 4.* Revision 0 – November 2012).
[3] Input from local commercial logging operators in the Kootenai Valley. (CDM Smith. 2012. *Sampling and Analysis Plan/Quality Assurance Project Plan. 2012 Commercial Logging Activity-Based Sampling.* August 2012.)
[4] ATSDR 2001. *Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana.* A Report to the Community. August 23, 2001.

<u>Source Notes:</u>

a) Hours/day cleaning woodstoves are based on interviews with residents that use wood burning stoves for heating; residents spend about 15 minutes per event.
b) Days/year for CTE is assumed to be 1/2 RME value.
c) Days/year removing ash from woodstove are site specific based on interviews with residents [5].
d) RME days/year adjusted to account for an area use factor of 0.1 (i.e., 10% of logging time is spent within OU3).
e) CTE days/year adjusted to account for an area use factor of 0.05 (i.e., 5% of logging time is spent within OU3).
f) ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The raw data from this study were used to derive the median and 95th percentile for use at CTE and RME exposure duration values, respectively. Statistics were provided by Ted Larson (ATSDR) via email on 10/14/15. The 95th percentile was selected in accordance with EPA RAGS, Part A guidance (EPA 1989) which states, "[i]f statistical data are available, use the 95th percentile value for [RME] exposure time".

<u>Notes:</u>
ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - environmental protection agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 3-5 ESTIMATED RISKS FROM EXPOSURES TO LA DURING WOODSTOVE ASH REMOVAL ACTIVITIES

Libby Asbestos Superfund Site

Panel A: Based on Reasonable Maximum Exposure (RME)

Exposure Area*	Mean EPC+ (PCME LA s/cc)	Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Within OU3 Boundary	0.038	0.25	48	52	0.0010	**7E-06**	**0.4**
Outside OU3 Boundary	0.0079	0.25	48	52	0.0010	**1E-06**	**0.09**
Outside NPL Boundary	0.0029	0.25	48	52	0.0010	**5E-07**	**0.03**

Panel B: Based on Central Tendency Exposure (CTE)

Exposure Area*	Mean EPC+ (PCME LA s/cc)	Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Within OU3 Boundary	0.038	0.25	24	22	0.00022	**1E-06**	**0.1**
Outside OU3 Boundary	0.0079	0.25	24	22	0.00022	**3E-07**	**0.02**
Outside NPL Boundary	0.0029	0.25	24	22	0.00022	**1E-07**	**0.007**

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

*Exposure Areas:

Within OU3 Boundary: includes ABS Areas A, C, D, E, F, H, and "Near Mine" (aka Area 1)

Outside OU3 Boundary: includes ABS Areas B, G, I and "Near Flower Creek"

Outside NPL Boundary: includes "Near Bear Creek"

Notes:

EPC = exposure point concentration

HQ = hazard quotient

LA = Libby amphibole asbestos

PCME = phase contrast microscopy equivalent

s/cc = structures per cubic centimeter

TABLE 3-6 ESTIMATED RISKS FROM EXPOSURES TO LA DURING WOODSTOVE ASH REMOVAL ACTIVITIES - STRATIFIED BY ABS AREA

Libby Asbestos Superfund Site

Exposure Area*	ABS Area	Mean EPC+ (PCME LA s/cc)	Based on RME Parameters					
			Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Within OU3 Boundary	Near Mine (Area 1)	0.14	0.25	48	52	0.0010	**2E-05**	**2**
	Area A	0.029	0.25	48	52	0.0010	**5E-06**	**0.3**
	Area C	0.032	0.25	48	52	0.0010	**6E-06**	**0.4**
	Area D	0.015	0.25	48	52	0.0010	**3E-06**	**0.2**
	Area E	0.038	0.25	48	52	0.0010	**7E-06**	**0.4**
	Area F	0.0057	0.25	48	52	0.0010	**1E-06**	**0.06**
	Area H	0.0084	0.25	48	52	0.0010	**1E-06**	**0.09**
Outside OU3 Boundary	Area B	0.015	0.25	48	52	0.0010	**3E-06**	**0.2**
	Area G	0	0.25	48	52	0.0010	**0E+00**	**0**
	Area I	0.0090	0.25	48	52	0.0010	**2E-06**	**0.1**
	Near Flower Creek	0.0074	0.25	48	52	0.0010	**1E-06**	**0.08**
Outside NPL Boundary	Near Bear Creek	0.0029	0.25	48	52	0.0010	**5E-07**	**0.03**

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

Original ABS areas evaluated in the *Site-wide HHRA* (EPA 2015).

HQ > 1

*Exposure Areas:

Within OU3 Boundary: includes ABS Areas A, C, D, E, F, H, and "Near Mine" (aka Area 1)

Outside OU3 Boundary: includes ABS Areas B, G, I and "Near Flower Creek"

Outside NPL Boundary: includes "Near Bear Creek"

Notes:

EPC = exposure point concentration

HQ = hazard quotient

LA = Libby amphibole asbestos

PCME = phase contrast microscopy equivalent

s/cc = structures per cubic centimeter

TABLE 4-1 ESTIMATED RISKS FOR OU3-RELATED EXPOSURES AS PRESENTED IN THE SITE-WIDE HHRA

Libby Asbestos Superfund Site

Receptor Population	Exposure Scenario	Exposure Area*	EPC	Based on RME Parameters					
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Cancer Risk	Non-cancer HQ
Mine Trespasser	ATV-riding on the mine	Mine (on/off-road)	0.014	4	10	52	0.0034	**8E-06**	**0.5**
	Rockhound	Disturbed mine area	0.14	6	3	52	0.0015	**4E-05**	**2**
Recreational Visitor	Hiking	Rainy Creek	0.0093	3.6	20	52	0.0061	**1E-05**	**0.6**
		Forest, near	0.00050	8	50	52	0.034	**3E-06**	**0.2**
		Forest, intermed.	0.00065	8	50	52	0.034	**4E-06**	**0.2**
		Forest, far	0.00023	8	50	52	0.034	**1E-06**	**0.09**
	ATV-riding in the forest	Forest, near	0.0014	4	50	52	0.017	**4E-06**	**0.3**
		Forest, intermed.	0.00050	4	50	52	0.017	**1E-06**	**0.09**
		Forest, far	0.00022	4	50	52	0.017	**6E-07**	**0.04**
	Campfire building/burning	Forest, near	0.0024	2	50	52	0.0085	**3E-06**	**0.2**
		Forest, intermed.	0.0022	2	50	52	0.0085	**3E-06**	**0.2**
		Forest, far	0.00046	2	50	52	0.0085	**7E-07**	**0.04**
	Driving on forest roads	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.00013	3	50	52	0.013	**3E-07**	**0.02**
		Forest, far	0	3	50	52	0.013	**0E+00**	**0**
	Fishing/boating	Kootenai River	0	8	60	52	0.041	**0E+00**	**0**
Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.00032	8	30	10	0.0039	**2E-07**	**0.01**
		Forest, far	0.00020	8	30	10	0.0039	**1E-07**	**0.009**
	Building slashpile	~1 mile from mine	0.12	8	10	10	0.0013	**3E-05**	**2**
	During slashpile burn (personal air)	~1 mile from mine	0.011	4	10	10	0.00065	**1E-06**	**0.08**
	During slashpile burn dry mop-up	~1 mile from mine	0.13	2	10	10	0.00033	**7E-06**	**0.5**
	During slashpile burn wet mop-up	~1 mile from mine	0.068	2	10	10	0.00033	**4E-06**	**0.2**
Outdoor Worker (firefighter)	Cutting firelines by hand	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.0069	10	14	10	0.0023	**3E-06**	**0.2**
		Forest, far	0.0045	10	14	10	0.0023	**2E-06**	**0.1**
		Forest, NPL boundary	0.00017	10	14	10	0.0023	**7E-08**	**0.004**
	Cutting firelines with heavy machinery	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.0025	10	14	10	0.0023	**1E-06**	**0.06**
		Forest, far	0.0016	10	14	10	0.0023	**6E-07**	**0.04**
	During understory burn	~1 mile from mine	0.078	3	7	25	0.00086	**1E-05**	**0.7**
	During understory burn dry mop-up	~1 mile from mine	0.75	2	7	25	0.00057	**7E-05**	**5**
	During understory burn wet mop-up	~1 mile from mine	0.18	2	7	25	0.00057	**2E-05**	**1**
	Ground-based firefighter activities	Souse Gulch	0.00031	15	39	25	0.024	**1E-06**	**0.08**
	Air-based wildfire suppression	Souse Gulch	0	15	39	25	0.024	**0E+00**	**0**

Receptor Population	Exposure Scenario	Exposure Area*	EPC	Based on RME Parameters					
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/day)	EF (days/year)	ED (years)	TWF	Cancer Risk	Non-cancer HQ
Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	8	24	6	0.0019	**1E-06**	**0.07**
	Hooking/skidding, processing timber	~1 mile from mine	0.10	10	24	12	0.0047	**8E-05**	**5**
	Mechanical Processing	~1 mile from mine	0.0015	10	24	12	0.0047	**1E-06**	**0.08**
	Site restoration	~1 mile from mine	0.032	10	24	12	0.0047	**3E-05**	**2**
	Simulated milling (chipping)	~1 mile from mine	0.0068	10	24	12	0.0047	**5E-06**	**0.4**
	Hand Felling	~4 miles from mine	0.0022	8	24	6	0.0019	**7E-07**	**0.05**
	Skidding/Hooking	~4 miles from mine	0.00065	10	24	12	0.0047	**5E-07**	**0.03**
	Mechanical Processing	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
	Cutting slabs (pre-milling)	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
	Simulated milling (chipping)	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
	Site Restoration	~4 miles from mine	0.0040	10	24	12	0.0047	**3E-06**	**0.2**
Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	---	---	---	---	---	---	---
		Forest, intermed.	0.0011	10	15	40	0.0098	**2E-06**	**0.1**
		Forest, far	0.00014	10	15	40	0.0098	**2E-07**	**0.01**
	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.25	48	52	0.0010	**2E-05**	**2**
		Flower Creek	0.0074	0.25	48	52	0.0010	**1E-06**	**0.08**
		Bear Breek	0.0029	0.25	48	52	0.0010	**5E-07**	**0.03**
	Downwind of understory burn	~1 mile from mine	0.00052	24	8	52	0.016	**1E-06**	**0.09**
	Dowwind of slashpile burn	~1 mile from mine	0.00047	24	8	52	0.016	**1E-06**	**0.09**
	Downwind stations during wildfire	Souse Gulch	0	24	8	52	0.016	**0E+00**	**0**

Source: Panel A of Table 6-17, Table 8-5, and Table 8-6 in the Site-wide HHRA (EPA 2015)

HQ > 1

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

--- = No ABS air samples have been collected within two miles from the mine for this scenario

*Distances from the mine are defined as follows:

Forest, near: within two miles from the mine

Forest, intermed.: between two and six miles from the mine

Forest, far: greater than or equal to six miles from the mine

Forest, NPL boundary: locations along the NPL boundary evaluated in the Nature & Extent Forest study

Notes:

ATV - all terrain vehicle

Conc. - concentration

CTE - central tendency exposure

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

NPL - National Priorities List

OU - operable unit

PCME - phase contrast microscopy equivalent

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

TABLE 4-2 SUMMARY STATISTICS FOR ABS AIR SAMPLES COLLECTED DURING HOOKING/SKIDDING ACTIVITIES

Libby Asbestos Superfund Site

Panel A: Summary Statistics for each ABS Area

Exposure Area*	ABS Area	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
				Mean	Maximum	
Within OU3 Boundary	~1 mile from mine (Area 1)	5	5	0.10	0.16	0.010
	Area A	5	1	0.00075	0.0038	0.0038
	Area C	5	4	0.044	0.12	0.0073
	Area D	5	3	0.015	0.037	0.0067
	Area E	5	5	0.038	0.080	0.0037
	Area F	5	1	0.0011	0.0038	0.0060
	Area H	5	5	0.023	0.067	0.0045
Outside OU3 Boundary	Area B	5	0	0	0	0.0038
	Area G	5	2	0.0030	0.0075	0.0075
Outside NPL Boundary	~4 miles from mine (Area 2)	4	1	0.00065	0.0026	0.0063

Original ABS areas evaluated in the *Site-wide HHRA* (EPA 2015).

Panel B: Summary Statistics for each Exposure Area

Exposure Area*	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Within OU3 Boundary	35	24	0.032	0.16	0.0060
Outside OU3 Boundary	10	2	0.0015	0.0075	0.0056
Outside NPL Boundary	4	1	0.00065	0.0026	0.0063

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

*Exposure Areas:

Within OU3 Boundary: includes ABS Areas A, C, D, E, F, H, and logging area ~1 mi. from mine (aka Area 1)
Outside OU3 Boundary: includes ABS Areas B and G
Outside NPL Boundary: includes logging area ~4 mi. from mine (aka Area 2)

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
PCME - phase contrast microscopy equivalent
s/cc - structures per cubic centimeter

TABLE 4-3 ESTIMATED RISKS FROM EXPOSURES TO LA DURING HOOKING/SKIDDING ACTIVITIES
Libby Asbestos Superfund Site

Panel A: Based on Reasonable Maximum Exposure (RME)

Exposure Area*	Mean EPC+ (PCME LA s/cc)	Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Within OU3 Boundary	0.032	10	24	12	0.0047	**3E-05**	**2**
Outside OU3 Boundary	0.0015	10	24	12	0.0047	**1E-06**	**0.08**
Outside NPL Boundary	0.00065	10	24	12	0.0047	**5E-07**	**0.03**

Panel B: Based on Central Tendency Exposure (CTE)

Exposure Area*	Mean EPC+ (PCME LA s/cc)	Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Within OU3 Boundary	0.032	8	8	12	0.0013	**7E-06**	**0.5**
Outside OU3 Boundary	0.0015	8	8	12	0.0013	**3E-07**	**0.02**
Outside NPL Boundary	0.00065	8	8	12	0.0013	**1E-07**	**0.009**

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

HQ > 1

*Exposure Areas:
Within OU3 Boundary: includes ABS Areas A, C, D, E, F, H, and logging area ~1 mi. from mine (aka Area 1)
Outside OU3 Boundary: includes ABS Areas B and G
Outside NPL Boundary: includes logging area ~4 mi. from mine (aka Area 2)

Notes:
EPC = exposure point concentration
HQ = hazard quotient
LA = Libby amphibole asbestos
PCME = phase contrast microscopy equivalent
s/cc = structures per cubic centimeter

TABLE 4-4 ESTIMATED RISKS FROM EXPOSURES TO LA DURING HOOKING/SKIDDING ACTIVITIES - STRATIFIED BY ABS AREA

Libby Asbestos Superfund Site

Exposure Area*	ABS Area	Mean EPC+ (PCME LA s/cc)	Based on RME Parameters					
			Exposure Time [ET] (hrs/d)	Exposure Frequency [EF] (d/yr)	Exposure Duration [ED] (yrs)	Time-weighting Factor [TWF]	Cancer Risk	Non-cancer HQ
Within OU3 Boundary	~1 mile from mine (Area 1)	0.10	10	24	12	0.0047	**8E-05**	**5**
	Area A	0.00075	10	24	12	0.0047	**6E-07**	**0.04**
	Area C	0.044	10	24	12	0.0047	**4E-05**	**2**
	Area D	0.015	10	24	12	0.0047	**1E-05**	**0.8**
	Area E	0.038	10	24	12	0.0047	**3E-05**	**2**
	Area F	0.0011	10	24	12	0.0047	**9E-07**	**0.06**
	Area H	0.023	10	24	12	0.0047	**2E-05**	**1**
Outside OU3 Boundary	Area B	0	10	24	12	0.0047	**0E+00**	**0**
	Area G	0.0030	10	24	12	0.0047	**2E-06**	**0.2**
Outside NPL Boundary	~4 miles from mine (Area 2)	0.00065	10	24	12	0.0047	**5E-07**	**0.03**

+ Concentrations have been adjusted to account for preparation method (i.e., indirect prep adjustment factor of 2.5 applied)

Original ABS areas evaluated in the *Site-wide HHRA* (EPA 2015).
HQ > 1

*Exposure Areas:
Within OU3 Boundary: includes ABS Areas A, C, D, E, F, H, and logging area ~1 mi. from mine (aka Area 1)
Outside OU3 Boundary: includes ABS Areas B and G
Outside NPL Boundary: includes logging area ~4 mi. from mine (aka Area 2)

Notes:
EPC = exposure point concentration
HQ = hazard quotient
LA = Libby amphibole asbestos
PCME = phase contrast microscopy equivalent
s/cc = structures per cubic centimeter

Appendices

APPENDIX A

DETAILED DATA FOR
OU3 INVESTIGATIONS CONDUCTED IN 2016

[see also attached file "AppA_DetailedData.xlsx"]

APPENDIX A1
SUMMARY OF ASBESTOS RESULTS FOR THE WOODSTOVE ASH ABS
Libby Asbestos Superfund Site - Operable Unit 3

Distance from Mine	ABS Area	Event	Sample Date	Index ID		Sample Duration (min)	Sample Air Volume (L)	Preparation Method	GOs Examined	PCME LA			Pooled PCME LA			Mean PCME LA Conc. (s/cc)
				High Volume Filter	Low Volume Filter					Sensitivity (cc^{-1})	N Structures	Conc. (s/cc)	Sensitivity (cc^{-1})	N Structures	Conc. (s/cc)	
Within 2 miles of the mine	Area A	1	9/7/2016	WH-00012	WH-00013	6	24	Direct	88	0.018	1	0.018	0.0089	4	0.035	0.029
			9/7/2016	WH-00015	WH-00016	5	20	Direct	105	0.018	3	0.053				
		2	9/9/2016	WH-00054	WH-00055	5	20	Direct	105	0.018	3	0.053	0.0088	4	0.035	
			9/9/2016	WH-00056	WH-00057	5	20	Direct	108	0.017	1	0.017				
		3	9/12/2016	WH-00236	WH-00237	5	10	Direct	107	0.034	1	0.034	0.017	1	0.017	
			9/12/2016	WH-00238	WH-00239	5	10	Direct	108	0.035	0	0				
	Area C	1	9/9/2016	WH-00063	WH-00064	5	20	Direct	105	0.018	2	0.036	0.0088	3	0.026	0.032
			9/9/2016	WH-00066	WH-00067	5	20	Direct	108	0.017	1	0.017				
		2	9/12/2016	WH-00247	WH-00248	5	10	Direct	108	0.033	0	0	0.017	0	0	
			9/12/2016	WH-00249	WH-00250	5	10	Direct	84	0.034	0	0				
		3	9/14/2016	WH-00300	WH-00301	5	10	Direct	84	0.035	3	0.10	0.017	4	0.069	
			9/14/2016	WH-00317	WH-00318	5	10	Direct	84	0.035	1	0.035				
	Area D	1	9/7/2016	WH-00023	WH-00024	5	20	Direct	110	0.017	0	0	0.0087	2	0.017	0.015
			9/7/2016	WH-00025	WH-00026	5	20	Direct	104	0.018	2	0.036				
		2	9/9/2016	WH-00071	WH-00072	5	20	Direct	108	0.017	1	0.017	0.011	1	0.011	
			9/9/2016	WH-00073	WH-00074	5	10	Direct	110	0.034	0	0				
		3	9/12/2016	WH-00252	WH-00253	5	10	Direct	86	0.033	0	0	0.017	1	0.017	
			9/12/2016	WH-00254	WH-00255	5	10	Direct	84	0.034	1	0.034				
Between 2-6 miles from the mine	Area B	1	9/7/2016	WH-00018	WH-00019	5	20	Direct	109	0.017	0	0	0.011	1	0.011	0.015
			9/7/2016	WH-00020	WH-00021	5	10	Direct	110	0.034	1	0.034				
		2	9/9/2016	WH-00059	WH-00060	5	10	Direct	108	0.034	0	0	0.017	1	0.017	
			9/9/2016	WH-00061	WH-00062	5	10	Direct	109	0.034	1	0.034				
		3	9/12/2016	WH-00242	WH-00243	5	10	Direct	108	0.035	1	0.035	0.017	1	0.017	
			9/12/2016	WH-00244	WH-00245	5	10	Direct	108	0.035	0	0				
	Area E	1	9/7/2016	WH-00028	WH-00029	5	10	Direct	108	0.035	0	0	0.017	6	0.10	0.038
			9/7/2016	WH-00030	WH-00031	5	10	Direct	107	0.034	6	0.20				
		2	9/9/2016	WH-00076	WH-00077	5	20	Direct	106	0.018	1	0.018	0.012	1	0.012	
			9/9/2016	WH-00078	WH-00079	5	10	Direct	108	0.035	0	0				
		3	9/12/2016	WH-00257	WH-00258	5	10	Direct	84	0.034	0	0	0.017	0	0	
			9/12/2016	WH-00259	WH-00260	5	10	Direct	85	0.034	0	0				
	Area F	1	9/7/2016	WH-00033	WH-00034	5	20	Direct	105	0.018	0	0	0.012	0	0	0.0057
			9/7/2016	WH-00035	WH-00036	5	10	Direct	108	0.035	0	0				
		2	9/9/2016	WH-00081	WH-00082	5	10	Direct	110	0.034	1	0.034	0.017	1	0.017	
			9/9/2016	WH-00083	WH-00084	5	10	Direct	108	0.035	0	0				
		3	9/12/2016	WH-00263	WH-00264	5	10	Direct	84	0.035	0	0	0.017	0	0	
			9/12/2016	WH-00265	WH-00266	5	10	Direct	84	0.035	0	0				
	Area G	1	9/7/2016	WH-00038	WH-00039	5	20	Direct	105	0.018	0	0	0.012	0	0	0
			9/7/2016	WH-00040	WH-00041	5	10	Direct	108	0.035	0	0				
		2	9/9/2016	WH-00086	WH-00087	5	10	Direct	108	0.035	0	0	0.017	0	0	
			9/9/2016	WH-00088	WH-00089	5	10	Direct	108	0.034	0	0				
		3	9/12/2016	WH-00268	WH-00269	5	10	Direct	84	0.035	0	0	0.017	0	0	
			9/12/2016	WH-00270	WH-00271	5	10	Direct	84	0.035	0	0				
	Area H	1	9/7/2016	WH-00044	WH-00045	5	20	Direct	110	0.017	1	0.017	0.0086	1	0.0086	0.0084
			9/7/2016	WH-00046	WH-00047	5	20	Direct	108	0.017	0	0				
		2	9/9/2016	WH-00091	WH-00092	5	10	Direct	112	0.033	0	0	0.017	1	0.017	
			9/9/2016	WH-00093	WH-00094	5	10	Direct	114	0.033	1	0.033				
		3	9/12/2016	WH-00273	WH-00274	5	10	Direct	84	0.035	0	0	0.017	0	0	
			9/12/2016	WH-00275	WH-00276	5	10	Direct	84	0.035	0	0				
	Area I	1	9/7/2016	WH-00049	WH-00050	6	24	Direct	104	0.018	0	0	0.0090	3	0.027	0.0090
			9/7/2016	WH-00051	WH-00052	5	20	Direct	104	0.018	3	0.054				
		2	9/9/2016	WH-00096	WH-00097	5	10	Direct	108	0.035	0	0	0.017	0	0	
			9/9/2016	WH-00098	WH-00099	5	10	Direct	84	0.035	0	0				
		3	9/12/2016	WH-00278	WH-00279	5	10	Direct	84	0.034	0	0	0.017	0	0	
			9/12/2016	WH-00280	WH-00281	5	10	Direct	84	0.035	0	0				

Notes:

filter analyzed

Filters were prepared and analyzed in basic accordance with TEM ISO 10312:1995(E) (ISO 1995), with all applicable Libby site-specific laboratory modifications.

ABS = activity-based sampling
cc^{-1} = per cubic centimeter of air
Conc. = concentration
GO = grid opening
ID = identification
ISO = International Organization for Standardization
L = liter
LA = Libby amphibole asbestos
min = minute
N = number
PCME = phase contrast microscopy - equivalent
s/cc = structures per cubic centimeter
TEM = transmission electron microscopy

APPENDIX A2
SUMMARY OF ASBESTOS RESULTS FOR THE HOOKING/SKIDDING ABS
Libby Asbestos Superfund Site - Operable Unit 3

Distance from Mine	ABS Area	Sample Date	Index ID		Sample Duration (min)	Sample Air Volume (L)	Preparation Method	GOs Examined	PCME LA				Pooled PCME LA	
			High Volume Filter	Low Volume Filter					Sensitivity (cc^{-1})	N Structures	Conc. [a] (s/cc)	Indirect-Adj. Conc. (s/cc)	Sensitivity (cc^{-1})	Indirect-Adj. Conc. (s/cc)
Within 2 miles of the mine	Area A	9/15/2016	WH-00325	WH-00326	30	120	Direct	67	0.0037	0	0	0	0.00075	0.00075
			WH-00327	WH-00328	30	120	Direct	66	0.0038	1	0.0038	0.0038		
			WH-00330	WH-00331	30	120	Direct	67	0.0037	0	0	0		
			WH-00332	WH-00333	30	120	Direct	66	0.0038	0	0	0		
			WH-00334 [b]	WH-00335	30	120	Direct	67	0.0037	0	0	0		
	Area C	8/31/2016	WH-00136	WH-00137	30	119	Direct	65	0.0038	0	0	0	0.0012	0.044
			WH-00139	WH-00140	30	120	Direct	65	0.0038	9	0.034	0.034		
			WH-00141	WH-00142	30	120	Indirect - Ashed	262	0.0073	22	0.16	0.064		
			WH-00143	WH-00144	30	121	Indirect - Ashed	194	0.0097	25	0.24	0.097		
			WH-00145	WH-00146	30	120	Indirect - Ashed	157	0.012	25	0.30	0.12		
	Area D	9/10/2016	WH-00224	WH-00225	30	118	Direct	84	0.0038	0	0	0	0.0012	0.015
			WH-00227	WH-00228	30	62	Direct	84	0.0073	3	0.022	0.022		
			WH-00229	WH-00230	30	60	Direct	84	0.0075	4	0.030	0.030		
			WH-00231	WH-00232	30	60	Direct	84	0.0075	5	0.037	0.037		
			WH-00233	WH-00234	30	60	Direct	84	0.0075	0	0	0		
Between 2-6 miles from the mine	Area B	9/14/2016	WH-00306	WH-00307	30	120	Direct	66	0.0038	0	0	0	0.00076	0
			WH-00309	WH-00310	30	120	Direct	66	0.0038	0	0	0		
			WH-00311	WH-00312	30	120	Direct	66	0.0038	0	0	0		
			WH-00313	WH-00314	30	120	Direct	66	0.0038	0	0	0		
			WH-00315	WH-00316	30	120	Direct	66	0.0038	0	0	0		
	Area E	9/16/2016	WH-00340	WH-00341	30	120	Direct	84	0.0037	6	0.022	0.022	0.00073	0.038
			WH-00343	WH-00344	30	120	Direct	85	0.0037	7	0.026	0.026		
			WH-00345	WH-00346	30	120	Direct	85	0.0037	10	0.037	0.037		
			WH-00347	WH-00348	30	120	Direct	85	0.0037	7	0.026	0.026		
			WH-00349	WH-00350	30	120	Direct	86	0.0036	22	0.080	0.080		
	Area F	9/1/2016	WH-00152	WH-00153	30	120	Direct	65	0.0038	0	0	0	0.0011	0.0011
			WH-00155	WH-00156	30	121	Indirect - Ashed	258	0.0073	0	0	0		
			WH-00157	WH-00158	30	60	Direct	67	0.0075	0	0	0		
			WH-00159	WH-00160	30	120	Direct	65	0.0038	1	0.0038	0.0038		
			WH-00161	WH-00162	30	60	Direct	67	0.0075	0	0	0		
	Area G	9/13/2016	WH-00288	WH-00289	30	60	Direct	84	0.0075	0	0	0	0.0015	0.0030
			WH-00290	WH-00291	30	61	Direct	84	0.0073	0	0	0		
			WH-00292	WH-00293	30	60	Direct	84	0.0075	1	0.0075	0.0075		
			WH-00294	WH-00295	30	60	Direct	84	0.0075	0	0	0		
			WH-00296	WH-00297	30	60	Direct	84	0.0075	1	0.0075	0.0075		
	Area H	8/30/2016	WH-00121	WH-00122	30	120	Direct	84	0.0037	3	0.011	0.011	0.00083	0.023
			WH-00124	WH-00125	30	120	Direct	84	0.0037	3	0.011	0.011		
			WH-00126	WH-00127	30	121	Direct	83	0.0037	5	0.019	0.019		
			WH-00128	WH-00129	30	121	Direct	82	0.0038	8	0.030	0.030		
			WH-00130	WH-00131	30	60	Direct	84	0.0074	9	0.067	0.067		

Notes:

filter analyzed

[a] Concentrations have not been adjusted for indirect preparation.

[b] This sample contains one or more magnesioriebeckite structures.

Filters were prepared and analyzed in basic accordance with TEM ISO 10312:1995(E) (ISO 1995), with all applicable Libby site-specific laboratory modifications.

ABS = activity-based sampling
cc^{-1} = per cubic centimeter of air
Conc. = concentration
GO = grid opening
ID = identification
ISO = International Organization for Standardization
L = liter
LA = Libby amphibole asbestos
min = minute
N = number
PCME = phase contrast microscopy - equivalent
s/cc = structures per cubic centimeter
TEM = transmission electron microscopy

APPENDIX B

DATA QUALITY ASSESSMENT FOR OU3 INVESTIGATIONS CONDUCTED IN 2016

APPENDIX B
DATA QUALITY ASSESSMENT FOR OU3 INVESTIGATIONS CONDUCTED IN 2016

Investigations at the Libby Asbestos Superfund Site (Site) have generated a large amount of data on Libby amphibole asbestos (LA) concentrations in air, which were used in the risk assessment to quantify potential human exposures and risks. The *Site-wide Human Health Risk Assessment (HHRA)* (U.S. Environmental Protection Agency [EPA] 2015), included a detailed data quality assessment (see Appendix E of the *Site-wide HHRA*) for the datasets used in the risk assessment.

B.1 Quality Assurance Program Overview

As described in Appendix E of the *Site-wide HHRA*, key elements of the Site quality assurance (QA) program include:

- Use of detailed EPA-approved quality assurance project plans (QAPPs) to guide all sample collection, preparation, and analysis efforts
- Use of Site-specific standard operating (SOPs) for sample collection, preparation, and analysis
- Extensive training of all field and laboratory staff
- Extensive review and checking by senior staff of the work performed by field and laboratory personnel
- Periodic internal and external audits of field and laboratory operations
- Iterative modifications to improve methods and document procedures used to address any issues or problems identified by field staff, laboratory staff, or data users
- Use of approved QA plans at project laboratories
- Use of electronic data management tools for recording and transferring data which include a variety of error checks
- Collection and analysis of a variety of field and laboratory quality control (QC) samples
- Validation and verification of electronic data in the project database

B.2 2016 Activity-based Sampling Investigation Quality Control Evaluation

A variety of field QC samples and analytical laboratory QC analyses were included as part of the 2016 activity-based sampling (ABS) investigation. A detailed evaluation of the QC results was performed by the EPA Quality Assurance Technical Support contractor, CB&I Federal Services, LLC (CB&I). CB&I also performed a formal data validation for the 2016 ABS investigation. The results of this evaluation are presented in the *Annual QA/QC Summary Report (2016)* (CB&I 2017). In brief, CB&I concluded:

- Blank sample (e.g., lot blanks, field blanks, laboratory blanks) results show inadvertent contamination of field samples with LA or other forms of asbestos is not of significant concern in the field or at the analytical laboratory.

- For transmission electron microscopy (TEM) analysis of air, there is generally high agreement (good concordance) for intra-laboratory analyses. Inter-laboratory analyses suggest, while results are generally acceptable, there are some between-laboratory differences in structure counting and recording methods. However, these differences are not expected to be a large source of uncertainty in reported air concentrations.

- No results were qualified during the data validation, which supports the conclusion the reported air concentrations used in the risk assessment are of high quality.

B.3 Other Data Quality Evaluation Metrics

Three additional data quality evaluation metrics were evaluated for air samples analyzed by TEM to ensure reported LA concentrations were of adequate quality and reliable to support risk management decision-making. This included the confirmation the TEM analysis stopping rules were achieved, a test of filter loading evenness, and an assessment of indirectly prepared filters. Each of these metrics are discussed further below.

B.3.1 Confirmation of TEM Analysis Stopping Rules

Specific requirements for the TEM analysis of air samples collected in 2016 are in the governing QAPP, *2016 Woodstove Ash and Hooking/Skidding Activity-based Sampling Investigation* (MWH Americas, Inc. 2016). These requirements include the TEM analysis stopping rules. In general, three alternative stopping rules were specified for TEM analyses to ensure resulting data are adequate:

1. The target analytical sensitivity (TAS) to be achieved
2. A maximum number of LA structures to be counted
3. A maximum area of filter to be examined

When one of these stopping rules is met, the TEM analyst can stop counting grid openings and the analysis is complete.

Target Analytical Sensitivity. The TAS was determined for the ABS investigation based on a back-calculated risk-based concentration (RBC), which was specific to the receptor and exposure scenario, to ensure the resulting achieved analytical sensitivities would be adequate to support Site-specific risk estimates and decision-making. For the 2016 hooking/skidding ABS samples, 24 of the 40 (60%) individual air filter analyses achieved the TAS of 0.0038 per cubic centimeters of air (cc^{-1}). For the 2016 woodstove ash ABS samples, 17 of the 54 (31%) individual air filter analyses achieved the TAS of 0.018 cc^{-1}. However, the pooled achieved sensitivity (combined across multiple air filters from the same ABS area) achieved the TAS for all ABS areas for both scenarios (see **Appendix A1** and **Appendix A2**).

Maximum Number of LA Structures. For filters having high asbestos loading, reliable estimates of concentration may be achieved before achieving the TAS. This is because the uncertainty around a TEM estimate of asbestos concentration in a sample is a function of the number of structures observed during the analysis. For the 2016 ABS investigation, the maximum number of LA structures was 25 phase contrast microscopy-equivalent[1] (PCME) LA structures (meaning the analysis could stop if 25 PCME LA structures were recorded regardless of the achieved sensitivity). Only 2 hooking/skidding ABS air analyses (both from Area C) stopped because they achieved the maximum number of PCME LA structures stopping rule (see **Appendix A2**). Typically, most samples had fewer than 10 PCME LA structures. Because of this, the exposure estimates used in the risk assessment are uncertain due Poisson counting error (analytical uncertainty) as well as sampling variability.

[1] See Section 2.1.3 of the Site-wide HHRA Addendum for a discussion of PCME.

Maximum Filter Area to be Examined. The number of grid openings that must be examined during a TEM analysis of an air sample depends upon the TAS, the air sample volume, and – if an indirect preparation was necessary – the dilution needed during the indirect preparation (i.e., f-factor). Depending upon these inputs, the number of grid openings that would need to be examined to achieve the TAS may become excessive. For the 2016 ABS investigation, the maximum filter area stopping rule was as follows:

ABS Scenario	Maximum Filter Area Stopping Rule
Hooking/Skidding ABS	Direct preparation: 0.85 mm^2 (about 85 grid openings[2]) Indirect preparation: 3.35 mm^2 (about 335 grid openings)
Woodstove Ash ABS	Direct preparation: 1.1 mm^2 (about 110 grid openings) Indirect preparation: 4.4 mm^2 (about 440 grid openings)

ABS = activity-based sampling
mm^2 = square millimeters

For the hooking/skidding ABS air analyses, 14 of the 40 (35%) analyses met the maximum filter area stopping rule. For the woodstove ash ABS air analyses, 37 of the 54 (69%) analyses met the maximum filter area stopping rule. Analyses stopped due to the maximum filter area stopping rule have the largest uncertainty relative to the other stopping rules described above. If desired, supplemental TEM analysis (i.e., examination of additional grid openings using the archived ABS air filters) could be performed for these datasets to reduce uncertainties. However, as noted above, the pooled achieved sensitivity (combined across multiple air filters from the same ABS area) achieved the TAS for all ABS areas for both scenarios, so additional analysis is not likely to be necessary to support risk-based decision-making.

B.3.2 Evenness of Air Filter Loading

An analysis of an air filter by TEM assumes the filter is evenly loaded (i.e., fibers are distributed at random across the filter). The assessment of filter loading evenness is evaluated using a Chi-square (CHISQ) test, as described in Annex F2 of the International Organization for Standardization (ISO) Method 10312:1995(E). If a filter fails the CHISQ test for evenness, the reported result may not be representative of the true concentration in the sample, and the results should be given low confidence. All the 2016 ABS air samples passed the CHISQ test (i.e., p value ≥ 0.001). Therefore, it is concluded uneven filter loading is not of significant concern and is not a source of uncertainty for air samples used in the risk assessment.

B.3.3 Indirect Preparation of Air Filters

If an ABS air filter was deemed to be overloaded, or if loose material was noted in the air cassette or adhering to the cowl, the filter was prepared indirectly (with ashing) in accordance with the indirect filter preparation procedures in Libby-specific SOP EPA-LIBBY-08. For chrysotile asbestos, indirect preparation tends to increase structure counts due to dispersion of bundles and clusters; however, the effects of indirect preparation on amphibole asbestos are generally much smaller, usually only increasing concentrations by a factor of 2-3 (Goldade and O'Brien 2014).

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[2] Assuming a grid opening area of 0.01 mm^2. The actual number of grid openings will depend upon the grid opening area, which may vary by laboratory.

There were no woodstove ash ABS air samples which required indirect preparation. Only 4 of 40 hooking/skidding ABS air samples required indirect preparation (3 samples from ABS Area C and 1 sample from ABS Area F) (see **Appendix A2**). To reduce the potential for bias due to indirect filter preparation, PCME LA concentrations for all indirectly-prepared air samples were adjusted (decreased) by a factor of 2.5. This factor was based on Libby-specific studies of the potential effect of indirect preparation on air samples (see Appendix D of the *Site-wide HHRA*). The actual effect of indirect preparation likely depends upon the nature of the LA structures present on the filter, which could differ depending upon the source material (e.g., soil, tree bark, duff), the sampling location (e.g., proximity to the mine site), and the type of disturbance activity. Hence, the estimated air concentration, calculated using an adjustment factor of 2.5, may be higher or lower than the true concentration.

B.4 Data Quality Assessment Summary and Conclusions

Investigations at the Site have generated a large amount of data on the LA concentration in air, which were used in the risk assessment to quantify potential human exposures and risks. The EPA developed and implemented an extensive a QA/QC program for the Site to ensure the quality of the data collected could be evaluated to ensure they were adequate to support management decisions on potential risks to human health from exposures to LA.

Taken together, these results indicate the QA/QC procedures used at the Site have been effective in ensuring the data collected are of high quality. As such, these data are of acceptable quality and are reliable and appropriate to support risk management decision-making.

B.5 References

CB&I (CB&I Federal Services, LLC). 2017. *Annual Laboratory QA/QC Summary Report (2016) for Task Order 1021 Quality Assurance (QA) Support for Remedial Investigation/Feasibility Study (RI/FS) at Site OU3.* Prepared by The Data Auditing Group, Quality Assurance Technical Support Program. Prepared for U.S. Environmental Protection Agency, Region 8. June 9.

EPA (U.S. Environmental Protection Agency). 2015. *Site-Wide Human Health Risk Assessment, Libby Asbestos Superfund Site, Libby, Montana.* Final - November.

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